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Araştırma Makalesi Research Article

PRODUCTION AND CHARACTERIZATION OF B_4C REINFORCED AA7075 COMPOSITE METALLIC FOAM

Guzide Meltem LULE SENOZ*, Rabia CINAR DASKESEN

Atatürk University, Department of Metallurgical and Materials Engineering, Erzurum, Turkey

Keywords

Metallic Foam, Sponge Replication Technique, Metal Matrix Composite, Al-Zn-Mg Alloy, Microstructure.

Abstract

In this study, the production and characterization of open-cell composite metal foam using the replica method, also known as polymer impregnation, was investigated. Composite powders were prepared by alloying in a planetary ball mill for 1 hour using AA7075 aluminum powder and 10% by weight B_4C powder. Characterization and morphology analysis of the composite metal foam produced using the prepared composite powders were performed using XRD and SEM/EDS analyses. As a result of the analyses, it was observed that α-Al, B_4C, C phase as a result of the polyurethane sponge not being completely removed from the structure, and secondary and tertiary phases such as Al_3BC, AlB_2, $AlB_{12}C_2$ and $Al_3B_{48}C_2$ resulting from the sintering process were observed in the composite foam metal structure.

B_4C TAKVİYELİ AA7075 KOMPOZİT METAL KÖPÜK ÜRETİMİ VE KARAKTERİZASYONU

Anahtar Kelimeler

Metal Köpük, Sünger Replikasyon Tekniği, Metal Matrisli Kompozit, Al-Zn-Mg Alaşımı, Mikroyapı.

Öz

Bu çalışmada replika metodu diğer adıyla polimer emdirme metodu ile açık hücreli kompozit metal köpük üretimi ve karakterizasyonu araştırılmıştır. Kompozit tozlar AA7075 alüminyum tozu ve ağırlıkça %10 B_4C tozu kullanılarak gezegensel tip bilyeli öğütücüde 1 saat alaşımlanarak hazırlanmıştır. Hazırlanan kompozit tozlar kullanılarak üretilen kompozit metal köpüğün karakterizasyonu ve morfoloji incelemesi XRD ve SEM/EDS analizleri kullanılarak gerçekleştirilmiştir. Analizler sonucunda, kompozit köpük metal yapısında α-Al, B_4C, poliüretan süngerin yapıdan tam olarak uzaklaşmaması sonucu C fazı ve sinterleme prosesinden kaynaklanan Al_3BC, AlB_2, $AlB_{12}C_2$ ve $Al_3B_{48}C_2$ gibi ikincil ve üçüncül fazların oluştuğu gözlemlenmiştir.

Alıntı / Cite

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Yazar Kimliği / Author ID (ORCID Number)

G.M. Lüle Şenöz, 0000-0003-0870-1269
R. Çınar Daşkesen, 0000-0002-0822-686X

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1. Introduction

Recently, with the developing technology, the need for low-weight and high-strength constructions has been increasing in every field (Ashby et al., 2000). Metallic foams are in the group of materials that are in demand due to their lightness and durability in important industrial areas such as the aerospace and especially the automotive sector. Due to the porous internal structure in metallic foam, materials with low density show superior properties such as thermal insulation, sound insulation and vibration damping properties (Çinici, 2004; Güven, 2011). aluminum and its alloys; it is preferred more than other competitive materials due to its high resistance to corrosion, low densities, high thermal and electrical conductivity, ability to increase resistance with precipitation hardening, ease of workability and ease of purchase (Dahil, 2017). Foam metals produced using aluminum can be used in many engineering applications due to their high strength and superior wear properties (Baumeister et al., 1997; Duarte and Banhart, 2000; Tan et al., 2005; Banhart and Seeliger, 2008). Although aluminum is generally

* İlgili yazar / Corresponding author: meltem.lule@atauni.edu.tr, +90-442-231-6039

used in metal foam production, nickel (Gauthier et al., 2004) and especially titanium (Lee et al., 2008; Kashef et al., 2009; Kovtunov et al., 2015) and tantalum (Zardiackas et al., 2001) are used for biomedical applications. The most commonly used foam metal production methods include precision casting (Allen et al., 1959), casting around hollow spheres (Banhart and Seeliger, 2008), metal injection molding, spacer, metal powder rolling, and sintering. The costs of metal foams produced using these methods vary according to the structural complexity of the foam material, its quantity and the area in which it is applied/used. As the structure of the foam material produced progresses from simple shapes to complex shapes, the process becomes more difficult and therefore the cost increases. Another way is to create polymer foams loaded with metallic particles, remove the polymer and combine the particles (Zaman, 2011; Danacı, 2011). The production cost of foam metals produced by using the polymer impregnation method is more economical than other methods and is preferred by manufacturers day by day.

The aim of this study is to investigate the economical production of AA7075-B4C composite metal foams with low density and durable open cell structure using polymeric impregnation method. Composite powders were prepared by alloying in a planetary ball mill for 1 hour using AA7075 aluminum powder and 10% by weight B_4C powder. Characterization and morphology analysis of the composite metal foam produced using the prepared composite powders were performed using XRD and SEM/EDS analyses.

2. Material and Method

2.1. Material

The matrix material used in the experiments was commercially graded air gas atomized AA7075 powders (Purity: 99,9%) with average particle size of 55 µm. The chemical composition of AA7075 powder was given in Table 1. B_4C particles (Purity: 99.5%) with an average particle size of 4 µm was added as the reinforcement.

Table 1. Chemical Composition of AA7075

Components	Zn	Mg	Fe	Si	Zr	Mn	Cr	Cu	Al
Amount (wt%)	5,46	2,75	0,12	0,17	0,03	< 0,01	0,24	1,57	Balanced

2.2. Production of Composite Material

The calculated amount of AA7075 aluminum alloy powder and 10% by weight of B_4C powder were milled in a Retsch PM 400/2 planetary ball mill operating at 250 rpm for 60 minutes in order to prepare a homogenous mix. AA7075 aluminum alloy powder and B_4C powder were loaded into a 125 ml WC grinding jar with 10 mm diameter WC balls at a powder-ball ratio of 1:10. The milling procedure was carried out at a grinding speed of 250 rpm using 1 wt% fine zinc stearate powder as a process control agent (PCA) to minimize the cold welding between powder particles and thereby prevent agglomeration (Figure 1). To prevent overheating, the ball mill was stopped every 20 minutes and a break time of 10 minutes was given.

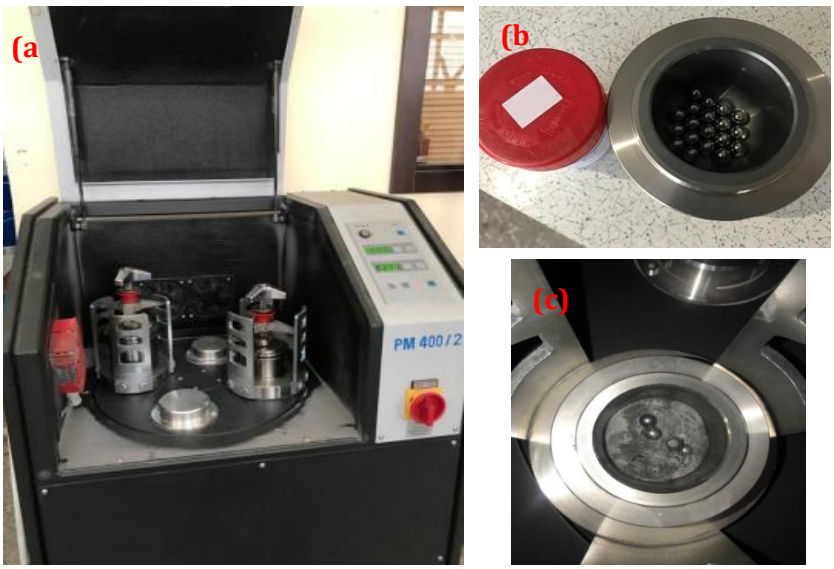

Figure 1. Schematic of The Mechanical Alloying Process (A) Retsch PM400/2 Ball Planetary Mill, (B) 125 Ml WC Grinding Jar With 10 Mm Diameter WC Balls, (C) Addition of 1% Zinc Stearate

2.3. Production of Open-Cell Metal Foams by Sponge Replication Technique

Replica method, also known as polymer impregnation method, was used for metal sponge production. The template used for this method is a 25 ppi (por/inch) polyurethane sponge (Figure 2). The density of the slurry mixture prepared with composite powders, polyvinyl alcohol (PVA) dissolved in water for 1 hour at 95°C used as binder, 1% polycarboxylic acid used as anti-caking dispersant, and distilled water, was determined according to previous literature studies and was prepared at 60% solid rate. The polyurethane sponges immersed in the prepared slurry and were kept in the slurry for 5 minutes, then removed from the slurry and kept on the platform for 2 hours at room temperature in order to remove the excess slurry from the surface. Then the samples were placed in a drying oven at 100°C for 24 hours to remove surface water. Binder and polyurethane sponge combustion were carried out in air for 3 hours at 250°C and 3 hours at 500°C in an air circulation oven, respectively. The sintering process, which is the final heat treatment, was carried out in a conventional tube furnace at 650°C for 3 hours under argon gas atmosphere.

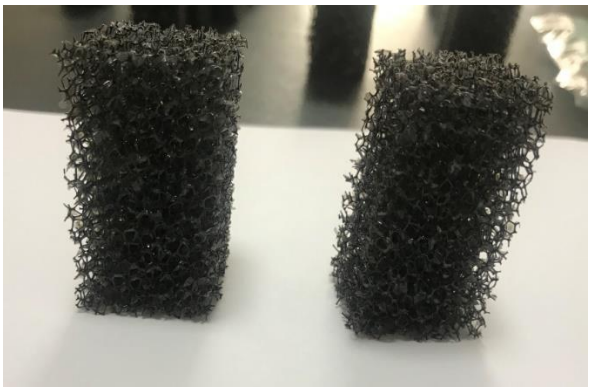

Figure 2. 25ppi Polyurethane Sponges (2.5cm x 2.5cm x 5cm)

The macrostructure images of the foam metals produced are shown in Figure 3. As can be seen in the figure, it has been observed that the produced aluminum foams have an open-cell foam structure, and their macro pores are in a round shape and in connection with each other.

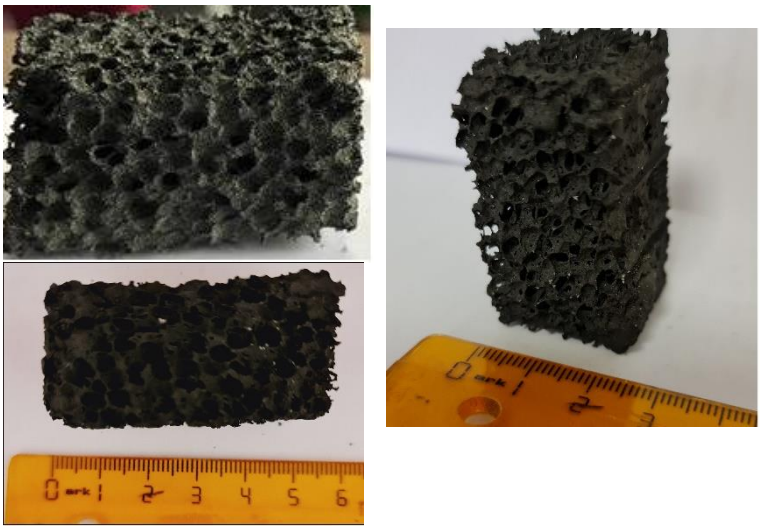

Figure 3. Macro Images of Produced Aluminum Foams

2.4. Characterization

XRD analysis was carried out in order to determine the existing phases before mechanical alloying, to examine the intermediate phases and their structures that may occur after alloying and during the production of composite metal foam. XRD measurements were carried out by using Rigaku-2200 D/Max X-ray powder diffractometer with Cu Kα radiation. The generator set was 45 kV, 40 mA. The diffraction patterns were collected at room temperature by step scanning in the range of $10 \leq 2\theta \leq 90°$ with a scan rate of 0.6–2° min^{-1}. PANalytical XPert-High Score Plus software was used for analysis of XRD spectra. The morphology of starting powders and composite metal foam were investigated by using scanning electron microscopy (SEM) equipped with JEOL JSM-6060 instrument. In

order to take images samples vacuum impregnated in epoxy resin were cut with a Struers Accutom-5 Linear Precision Saw at a feed rate of 0.05 mm / s. The surface of the samples was mechanically ground to 2000 grit SiC paper, then polished using 0.05 µm silica colloidal with 1 µm diamond paste. Lastly, Vickers hardness measurement was made on the foam samples that were sanded and polished after cold mounting. Hardness measurements using a 25g load (HV0.025) were obtained by taking the mean of at least five individual readings.

3. Experimental Results

3.1. XRD Analyses

The enlarged XRD patterns of as-received AA7075 and B_4C powders were illustrated in Figure 4. The XRD patterns of the AA7075 aluminum alloy showed characteristic five highest intensity peaks corresponding to the reflection plane of α (A1) at ≈38.48° (111), ≈44.72° (200), ≈ 65.10 (220), ≈78.23° (311) and ≈82.45° (222) while B_4C particles showed three intensity peaks at ≈23.5 (012), ≈34.5° (104), and ≈37.82° (021).

The XRD graph of the composite metal foam prepared using AA7075-10% B_4C composite powder, which is alloyed for 1 hour, was shown in Figure 5. As a result of the analysis, apart from the 5 basic α-Al peaks belonging to the AA7075 phase and the peaks belonging to the reinforcement element; peaks belonging to the C phase as a result of the polyurethane sponge not being completely removed from the structure and secondary and tertiary phases such as Al_3BC, AlB_2, $AlB_{12}C_2$ and $Al_3B_{48}C_2$ resulting from the sintering process were determined using the PANalytical XPert-High Score Plus software.

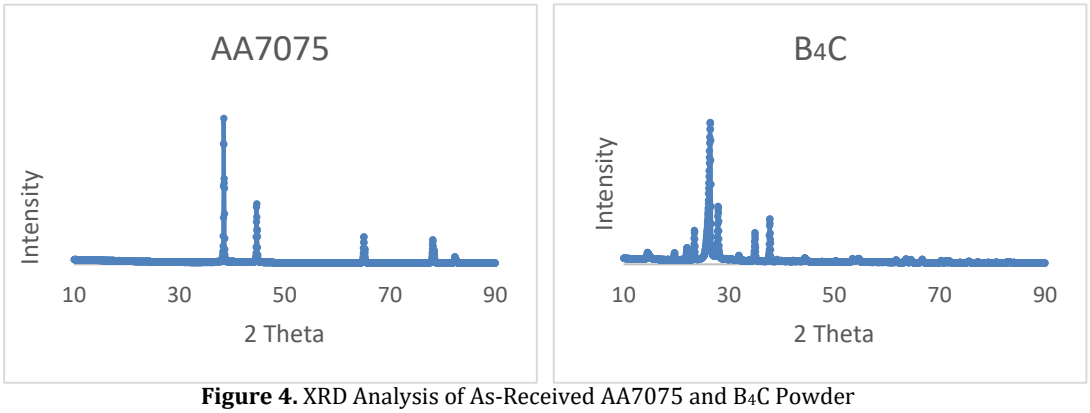

Figure 4. XRD Analysis of As-Received AA7075 and B_4C Powder

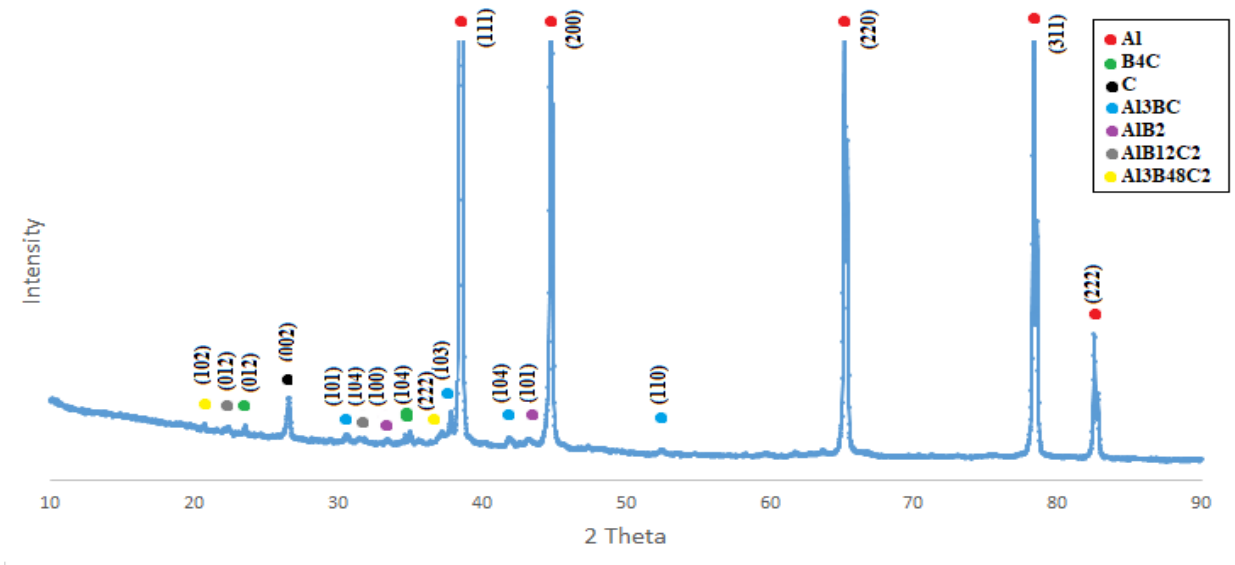

Figure 5. XRD Analysis of AA7075-10% B_4C Foam Metal Alloying For 1 Hour

3.2. SEM/EDS (Scanning Electron Microscopy) Analysis

SEM images of as-received AA7075 and B_4C powders are given in Figure 6. As seen in Figure 1, AA7075 particles have a spherical morphology of 55 µm particle size, while B_4C particles have an irregular morphology with sharp corners of 4 µm particle size.

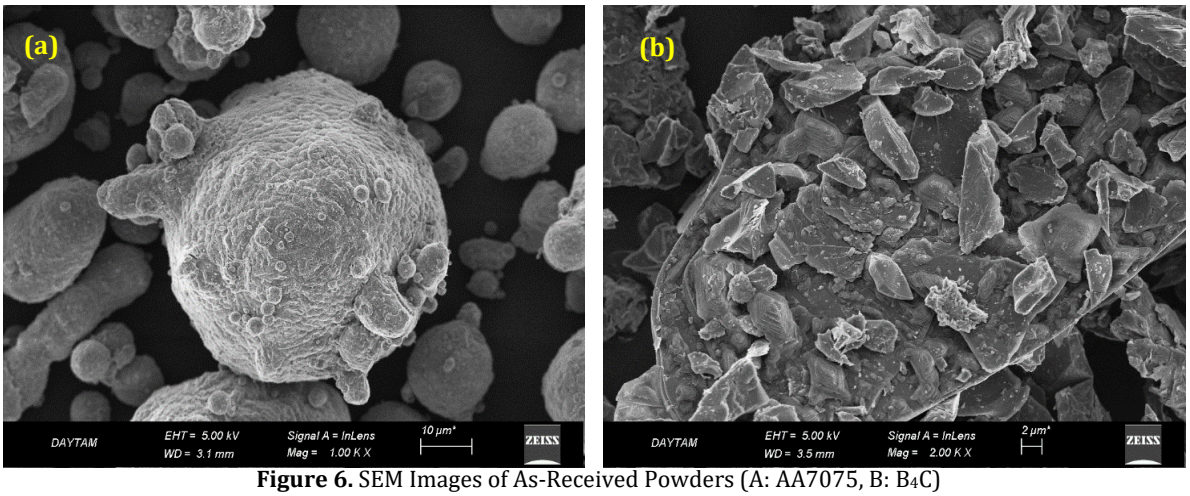

Figure 6. SEM Images of As-Received Powders (A: AA7075, B: B_4C)

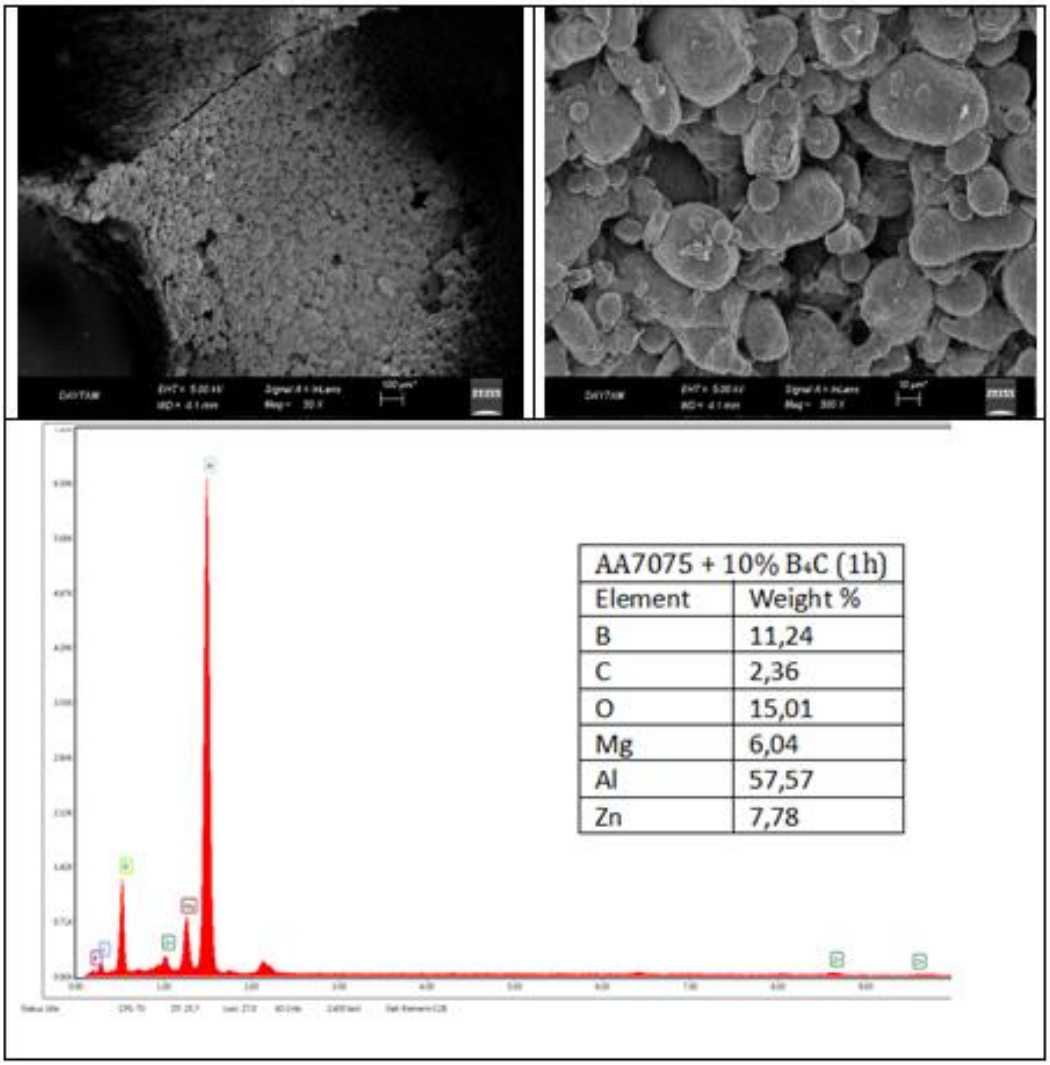

Figure 7. SEM/EDS Analysis of AA7075-10% B4C Foam Metal Alloying For 1 Hour

When the macro images are examined after sintering, it is observed that the macro pores are in a round structure and form an open-cell structure in connection with each other, retreat and shrinkage occur in the foam model due to the polyurethane sponge material moving away from the structure.

SEM/EDS analysis was carried out in order to examine the effects of the sintering process on the structure, macro and micro pores in the composite metal foam structure and the corners and edges of the metal foam cell walls. SEM images are given in two different forms as macro and micro (Figure 7). The foam metal cell walls and corners are clearly visible in the macro images. Due to insufficient sintering time, small, rounded geometry and localized grains were observed on the cell walls. It is thought that this problem will be minimized in longer sintering times. EDS analysis was performed on the surfaces of metal foam materials to determine if there was any reaction or contamination during the composite metal foam production and sintering process. In the results of EDS analysis, apart from Al, Zn and Mg elements belonging to AA7075 alloy and B and C elements belonging to reinforcement element, O element was observed. This is due to the affinity of the aluminum material for oxygen.

4. Result and Discussion

In this study, the production and characterization of open-cell composite metal foam using the replica method, also known as polymer impregnation, was investigated. Despite the oxide impurities in the case of aluminum, it has been shown that it is possible to produce AA7075-B_4C composite foam metal. The microhardness value (24±3 Hv) of the produced open-cell aluminum foam material is close to the hardness value (30.5 Hv) of the closed-cell aluminum foams produced by Alporas; however, lower from that of the closed-cell aluminum foams produced by Alulight Company (54.8 Hv). It is thought that sintering for 3 hours at 650C in an argon gas atmosphere is not sufficient, and more economical and durable cellular structures can be obtained by prolonging the sintering time or by sintering in different inert gas mixture atmospheres that can prevent oxidation.

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Conflict of Interest

No conflict of interest was declared by the authors.

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