SiC(p) REINFORCED ALUMINUM MATRIX COMPOSITES OBTAINED BY HOT PRESSING AND THEIR MECHANICAL PROPERTIES

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Abstract: *Metal matrix composites, containing Al (4 wt. % Cu) as the matrix material and SiC particles as the reinforcement, were produced by hot pressing. SiC(p) content of the composites were in 10 – 50 vol. % range. Appropriate amounts of Al, Cu and SiC powder were dry mixed and pressed at 25 MPa at 525 and 550 ^oC. Obtained composites were subjected to density and hardness measurements, 3 point bending tests and optical microscope investigations. Hardness was seen to increase continuously with the increase in the amount of SiC(p) from 54 HB10 (unreinforced matrix) to 148 HB10 (50 vol. % SiC). On the other hand, bending strength values of the composites first showed an increase up to 20 vol. % SiC and then decreased. Strain values decreased considerably, with the addition of SiC into the unreinforced matrix and the composites containing 40 and 50 vol. % SiC did not show plastic deformation before fracture. Yield strength and elastic moduli of the composites increased with the increase in the SiC amount. It was seen that the properties of Al%4Cu-SiC(p) composites, such as strength and hardness, can be adjusted by varying their SiC contents.*

Keywords: SiC(p) reinforced Al composite, hot pressing

1. Introduction

Metal matrix composites (MMCs) are technologically important materials since they can be tailored for obtaining a desired property, in order to be utilized in a specific application. The change in the properties can be imparted through varying the reinforcement amount, size or shape or the properties of the matrix metal. Particulate reinforced metal matrix composites have the advantage of ease in production, as compared to continuously reinforced composites.

Light and low strength metals such as aluminum and magnesium have been widely used as the matrix material for particulate reinforced MMCs. Widely used reinforcement particles are Al_2O_3, TiC, SiC and B_4C [1]. The main advantage of utilizing these hard ceramic particles is to enhance hardness and wear resistance. Al MMCs reinforced with hard ceramic particles can be utilized in bushes, automotive, train and aircraft brake parts, pistons for internal combustion engines, etc [2].

Aluminum matrix composites reinforced with SiC particles can be produced by melting techniques, such as infiltration, stir and/or squeeze casting [3], and solid state techniques such as powder metallurgy (PM) methods. In PM, extrusion [4,5] and hot pressing are commonly utilized. PM presents crucial advantages over liquid state techniques such as eliminating the wettability issues and possibility of addition of high fraction of reinforcements [1]. In the study of Abarghouie et al. [4], Al 2024 alloy powder was mixed with SiC particles and cold pressed and then hot extruded at 495 ^oC. Solution heat treatment was also performed at 495 ^oC and aging at 191 ^oC. It was reported that presence of SiC particles accelerated aging kinetics, when properly solutionized. In the study of Chawla et al. [5], effects of SiC content and particle size were examined, specifically on the fatigue behavior of the MMCs containing Al 2080 matrix. It was reported that decreasing SiC particle size and increasing its amount resulted in an increase in fatigue strength. Șahin [3] prepared 2014 Al-SiCp composites through stir-squeeze casting and investigated their machining characteristics.

Due to their lightweight, high hardness and wear resistance, SiC reinforced Al MMCs are promising structural materials. In addition, powder metallurgy routes are seen to be advantageous in their production. Therefore, in the present study, SiC particulate reinforced Al matrix composites were produced via powder metallurgy, specifically by hot pressing. Obtained composites were characterized by microstructural examinations, hardness measurements and 3 point bending tests.

2. Experimental Procedure

Aluminum (Merck, average particle size <10 microns) and copper (Alfa Aesar, average particle size 1-3 microns) powders were mixed at 4 wt% Cu ratio. SiC powder (Alfa Aesar, average particle size <10 microns) was added at amounts corresponding to 10-50 vol. % of the composite. The powders were mixed with 2 mm zirconia balls in a ceramic vial for 15 minutes. Then the powders were screened and placed into a die, which was made of hot work tool steel (AISI H13). The die, with its contents was placed into a hot press (MSE Technologies) and 50 MPa pressure was applied in cold state. The furnace of the hot press was adjusted so that it presented a heating rate of 5 ^oC/min. A 30 min soaking period was applied to the die at 525 and 550 ^oC. During heating and soaking, 25 MPa pressure was maintained. The obtained hot pressed samples were 37 mm long, 12 mm wide and 6 mm thick.

3 point bending tests were conducted according to ISO 3325 standard (span length is 25 mm), with a 50 kN capacity Universal Shimadzu unit. Hardness measurements were conducted according to Brinell 10 (HB10) scale (Bulut Makina, Turkey). Densities of the samples were determined according to Archimedes' principle, after weighing the samples in air and in water. Samples were cut, lapped on emery paper and polished with diamond paste, prior to microstructural examinations. Microstructures of the composites were investigated by an optical microscope (Nicon Eclipse LV150).

3. Results and Discussion

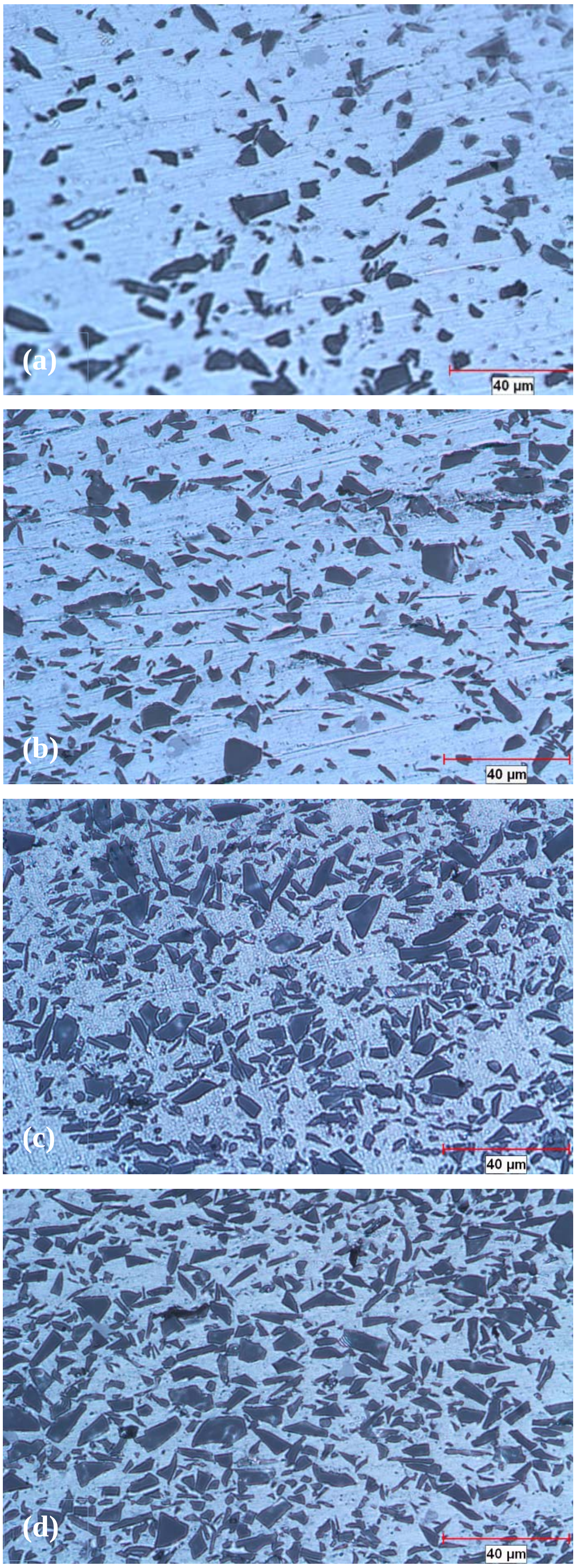
3.1. Microstructure of the Composites

Percent theoretical density values of the prepared composites were determined via dividing the measured density values by the theoretical density values of the composites and multiplying by 100. Percent theoretical densities of the composites hot pressed ad 525 ^oC were in 93.5 - 96.3 % range, whereas that of the composites hot pressed at 550 ^oC were in 94 - 99.6 % range.

The microstructure of the obtained SiC – Al(%4Cu) MMCs are presented in Fig.1 (optical microscopy, X500 magnification). In general, it was seen during the microscopical examinations that the composites obtained at 525 ^oC contained more amount of porosity than the composites obtained at 550 ^oC. This finding is in accord with the density measurements. The black angular particles in the given micrographs in Fig.1 are SiC. It can be seen in these micrographs that the area covered by the SiC particles increases with increasing SiC content of the composites. The SiC particles were seen to be homogenously distributed in the Al(%4Cu) matrix.

As can be seen in these figures, the particle size of SiC was generally smaller than 10 micrometers. However, there are some large particles of about 20 micrometers size.

In the optical micrographs, light gray particles were observed at some points, which are believed to be Al_2Cu intermetallic particles. These particles are believed to form with the reaction of Al and Cu during the liquid phase sintering of the Al-%4Cu system. At the sintering temperature, Cu has higher solubility in the formed liquid and upon solidification, formation of solid Al_2Cu particles takes place, since Cu has low solubility in solid Al at room temperature.



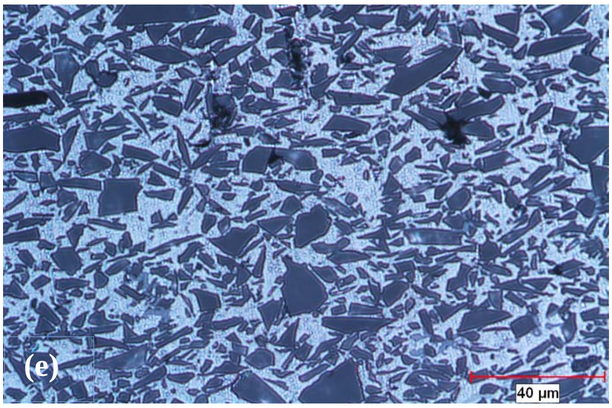


Fig. 1 Microstructures of composites obtained by hot pressing at 550 °C of Al(%4Cu)-SiC mixtures containing (a) 10 vol. % SiC, (b) 20 vol. % SiC, (c) 30 vol. % SiC, (d) 40 vol. % SiC, (e) 50 vol. % SiC.

3.2. Hardness of the Composites

Hardness of the unreinforced Al%4Cu matrix alloy was 54 HB10. Addition of SiC particles into the aluminum alloy matrix resulted in an increase in the hardness values. It can be seen in Fig. 2 that the hardness of the composites increased continuously with the increase in the amount of SiC(p) in the composites. Hardness of the composite which contained 50 vol. % SiC was 146 HB10.

Increase in the hardness of the composites with increasing SiC particle content may be attributed to restriction of the plastic deformation of the aluminum alloy matrix, due to the presence of the SiC particles.

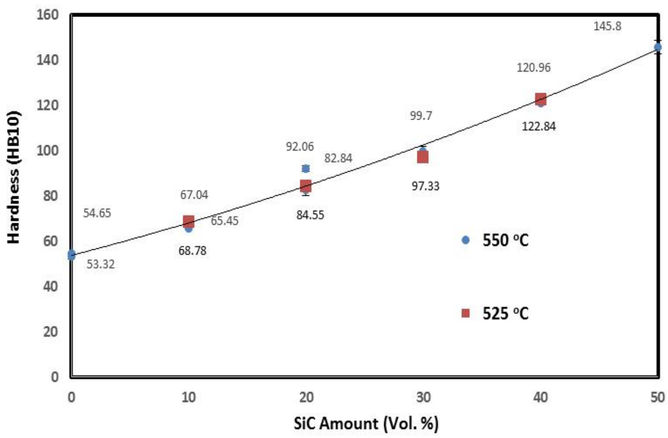


Fig. 2 Hardness of the unreinforced Al%4Cu matrix alloy and of the composites containing 10, 20, 30 and 40 vol. % SiC(p).

3.3. Bending Strength of the Composites

Unreinforced Al alloy sample and samples containing various amounts of SiC were subjected to 3 point bending tests. Bending strength of the unreinforced alloy which was sintered at 550 °C was 428 MPa. Addition of SiC particles to the aluminum matrix resulted in an increase in the bending strength up to 20 vol. % SiC content, with the highest strength of about 484 MPa (Fig. 3). Strength values were seen to decrease at higher SiC(p) contents. Bending strength of the composite which contained 50 vol. % SiC was 410 MPa. These results indicate that there is an optimum amount of SiC(p), which may be suggested as 20 vol. % in the present study. The increase in the strength of the composites may be attributed to the hindrance of plastic deformation of the Al alloy matrix, caused by the SiC particles. On the other hand, beyond a certain value of SiC content, strength of the composite decreases due to the decrease in the the amount of matrix phase.

It can be seen in Fig.3 that the samples hot pressed at 525 °C

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presented lower bending strength values, as compared to samples which were sintered at 550 °C. This can be attributed to higher amount of porosity in the samples sintered at 525 °C, as revealed by the density measurements. It can be suggested that 550 °C is more suitable for hot pressing of the Al%4Cu-SiC(p) composites.

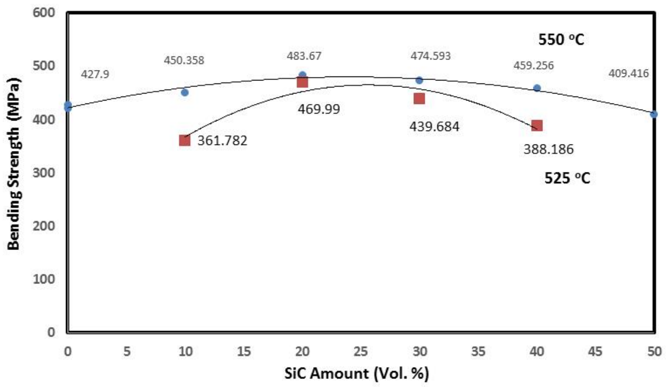

Fig. 3 *Thee point bending strength of the unreinforced Al%4Cu matrix alloy and of the composites containing 10, 20, 30 and 40 vol. % SiC(p), sintered at 525 and 550 °C.*

Bending strain values of the unreinforced sample and composite samples are presented in Fig. 4. Unreinforced sample presented strain values in 21-24 %, whereas addition of SiC resulted in an abrupt decrease in the strain values of the composites. 10 vol. % SiC containing composite had a strain value of 12.2 % and that of 50 vol. % SiC containing composite was 3.3 %. Composites sintered at 525 °C presented lower strain values as compared to composites sintered at 550 °C. This result may be attributed to lower % theoretical density or higher porosity of the composites sintered at 525 °C.

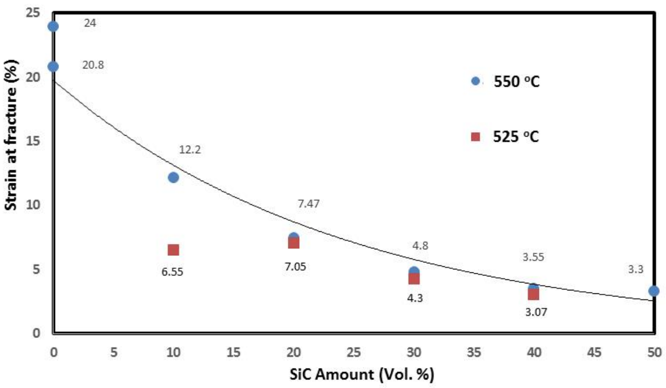

Fig. 4 *Thee point bending strain values of the unreinforced Al%4Cu matrix alloy and of the composites containing 10, 20, 30 and 40 vol. % SiC(p), sintered at 525 and 550 °C.*

In Fig. 5, three point bending stress vs. strain plots of the unreinforced Al%4Cu matrix alloy and of the obtained composites are presented. It can be seen in this figure that the bending strength values of the composites show a slight increase up to 20-30 vol. % SiC and then a decrease with the increase in the addition of SiC. The strain values, on the other hand show a continuous decrease and the strain values diminish down to about 3 %. The composites present a brittle fracture when they contain 40 and 50 vol. % SiC, with no plastic deformation before fracture. However, they present bending strength values as high as the unreinforced sample. The yield strength of the unreinforced Al%4Cu was about 180 MPa and yield strength, which can be determined as the point of departure from linearity of the stress-strain curves, appear to increase with the increase in the SiC content of the composites. In addition, elastic moduli of the composites, which can be stated as the slope of the linear portion of the stress-strain curves, are seen to increase with the SiC content of the composites.

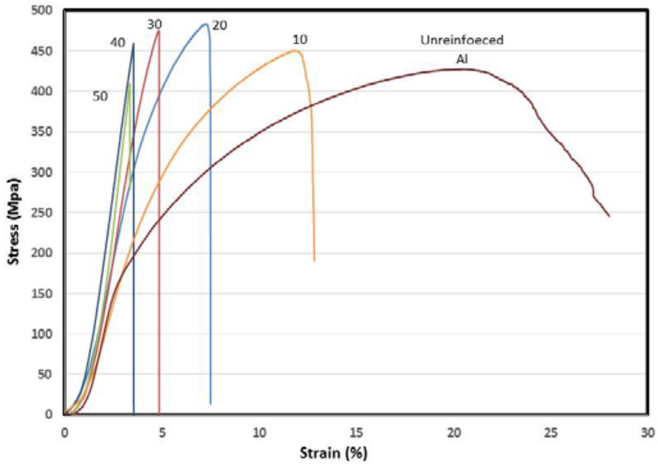

Fig. 5 *Three point bending stress – strain plots of the unreinforced Al%4Cu matrix alloy and of the composites containing 10, 20, 30 and 40 vol. % SiC(p), sintered 550 °C.*

SiC particulate reinforced Al%4Cu matrix composites were obtained by hot pressing. It was shown that the properties of the composites such as strength and hardness can be adjusted by varying the SiC content in the composites.

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