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Investigation of the Production and Mechanical Properties of Silicon Carbide-Reinforced Composites

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ABSTRACT: In this study, it was aimed to produce an intermetallic with low energy cost and better mechanical and physical properties with the microwave sintering method. Cupper matrix composites containing 4,8,12,16, and 20%SiC were fabricated by microwave furnace sintering at 1000°C, 1050°C, and 1100°C temperatures. Compounds formation between Cu–%10Cr and SiC powders was observed after sintering under Argon atmosphere. XRD, Scanning Electron Microscope, mechanical testing, and measurements were employed to characterize the properties of Cu + %10Cr ++4%SiC, Cu + %10Cr +8%SiC, Cu + %10Cr +12%SiC, Cu + %10Cr +16%SiC, and Cu + %10Cr +20%SiC composite specimens. The results of the test data applied to the samples were examined. For composite samples of Cu + 10% + 4% SiC composition at 1000 ° C, the hardness value was measured as 128 HV. The ceramic additive was made to increase the wear and corrosion resistance of the intermetallics.

Keywords: Powder metallurgy, Microwave Sintering, Ceramic-Metal Composites

Silisyum Karbür İle Güçlendirilmiş Kompozit Üretimi ve Mekaniksel Özellliklerinin Araştırılması

ÖZET: Bu çalışmada, mikrodalga sinterleme tekniği kullanılarak daha düşük enerji maliyeti ve iyi mekaniksel ve fiziksel özellikler elde edilmesi amaçlanmıştır. Bakır matriks tozları 4,8,12,16,20%SiC katkısı yapılarak güçlendilrilmiştir. Numuneler endüstriyel mikrodalga sinterleme fırını kullanılarak 1000°C, 1050°C ve 1100°C sıcaklıklarda argon atmosferinde 1 saat sürede sinterlenmişlerdir. Üretilen numunelere Taramalı Elektron Mikroskobu, X-Ray Difraksiyonu, mekaniksel test ve ölçümler uygulanarak numuneler karakterize edilmiştir. Numunelere uygulanan test ve bulgular sonucunda 1000 °C de sinterlenen Cu + 10% + 4% SiC kompozisyonuna ait numunler daha iyi özelliklere sahip olduğu belirlenmiştir. Bu kompozisyona ait Sertlik değeri 128HV olarak ölçülmüştür. CuCr intermetaliğine SiC katkısı aşınma ve korozyon direncini arttırmıştır.

Anahtar Kelimeler: Toz Metallurjisi, Mikrodalga Sinterleme, Seramik-Metal Kompozit

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INTRODUCTION

Copper has high electrical and thermal conductivity, low cost, and high ductility (Khereddine et al., 2013; Celikyurek et al. All, 2011; Wang et al.,2009). Cu and its alloys are used as heat-absorbing materials in the electrically mobile contact points. Composites are widely used in many fields such as welding electrodes (Liu et al. ,2017; Li et al.,2015; Zhang et al., 2016). The intermetallics and the intermetallic phases are the areas of interest of material science. Due to its physical and mechanical properties, Composites usage areas have increased in recent years. In some aspects, these materials are better than traditional materials (Ergin and Ozdemir,2014). Two or more pure element using are produced new materials. They have unique properties known as intermetallic compounds (Kumar and Sahni, 2016).

A different formation in increasing the ductility of Ni_3Al is directional solidification. These are some examples of high ductility values in strong intermetallic compounds (Stoloff, 1993). Pure copper is extremely hard to cast because of proneness and to surface cracking, porosity and shaping of internal cavities during casting. The casting characteristics of copper can be advanced by the supplemental of small amounts of elements like beryllium, silicon, nickel, and so on. Cast copper alloys are used for applications such as resistance welding electrodes, bearings, bushings, gears, fittings, valve bodies, and miscellaneous components for the chemical processing industry. Copper matrix composites are promising materials which are well suited for applications in electrical sliding contacts such as in homopolar machine and railway overhead current collection system (Tu et al.,2003), (Lee et al., 2000), (Tjong et al.,2000), (Lee et al.,1999). Nowadays, Cu–Cr alloys have common applications in voltage interrupters and touch cable because of its high electrical conductivity and high strength (Ghosh et al., 1997), (Morris et al.,1988), (Huber et al.,1997),(Peng et al.,2005)

The extents of alloying during milling and its structural and morphological features were analyzed. Vickers hardness and electrical conductivity of the vacuum sintered specimens were also investigated and compared with that of the microwave sintered specimens. According to Akhtar et al., addition of alloying elements and carbide particle reinforcement into the Cu matrix might increase the sintered density as well as (increase) the elevated temperature strength with improvement in hardness and wear resistance (Akhtar et al.,2009). It was insensitive to the presence of a third alloy element. It has been shown that the addition of ceramic does not affect the chromium transport in the copper matrix (Batawi et al., 1990). Cu matrix composite production of CrC particle rate increases as the material hardness value has increased (Uzun and Usca, 2018). In the production of Cu-matrix composites, the Cr-particle reinforcement is a positive contribution to the wear resistance of copper (Uzun et al., 2018).

In the present work, Composites work Cu-Cr-%4SiC, Cu-Cr-%8SiC, Cu-Cr-%12SiC, Cu-Cr-%16SiC, and Cu-Cr-%20SiC were fabricated at microwave furnace, microstructure was characterized and It was observed that best mechanical properties such as hardness and density.

MATERIAL AND METHODS

Experimental

Starting powders employed in this study were as follows: the purity of 99.8% for Cu-Cr powders with a particle size lower than 70 µm and the purity of 99.95% for SiC ceramic powders a particle size lower than 75µm. The composition of Cu-Cr-%4SiC, Cu-Cr-%8SiC, Cu-Cr-%12SiC, Cu-Cr-%16SiC, and Cu-Cr-

%20SiC powders specimens were prepared in 10g square prisma compressed as a 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 300 Bar was used for compacting all the powder mixtures. The cold pressed samples were underwent for a sintering at 1000°C, 1050°C, and 1100°C for 1 hour in a microwave 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 microstructural and EDX compositional analysis. The volumetric changes of Cu-Cr-%4SiC, Cu-Cr-%8SiC, Cu-Cr-%12SiC, Cu-Cr-%16SiC, and Cu-Cr-%20SiC composite materials after sintering were calculated 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.

RESULTS AND DISCUSSION

Characterization

In the current study, the samples prepared and shaped were sintered at 1000°C, 1050°C, and 1100°C in microwave furnace and made ready for physical, mechanical, and metallographic analysis.

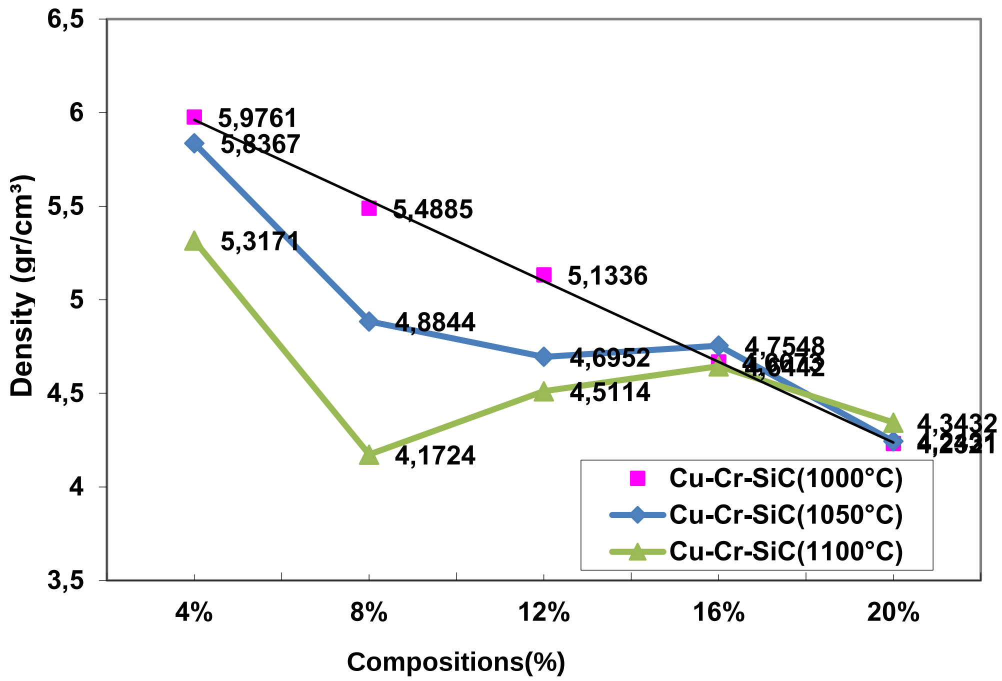

Figure 1. The density change with respect to sintering temperature

The micro hardness-temperature change diagram is shown in Fig 2. The micro hardness values of the composite samples were produced using microwave sintering technique within the these temperatures at 1000°C, 1050°C, and 1100°C. According to this, the highest micro hardness value in the composite samples produced using powder metallurgy method was observed to be 128 HV obtained for Cu + Cr + 4%SiC composite at 1000°C temperature composites.

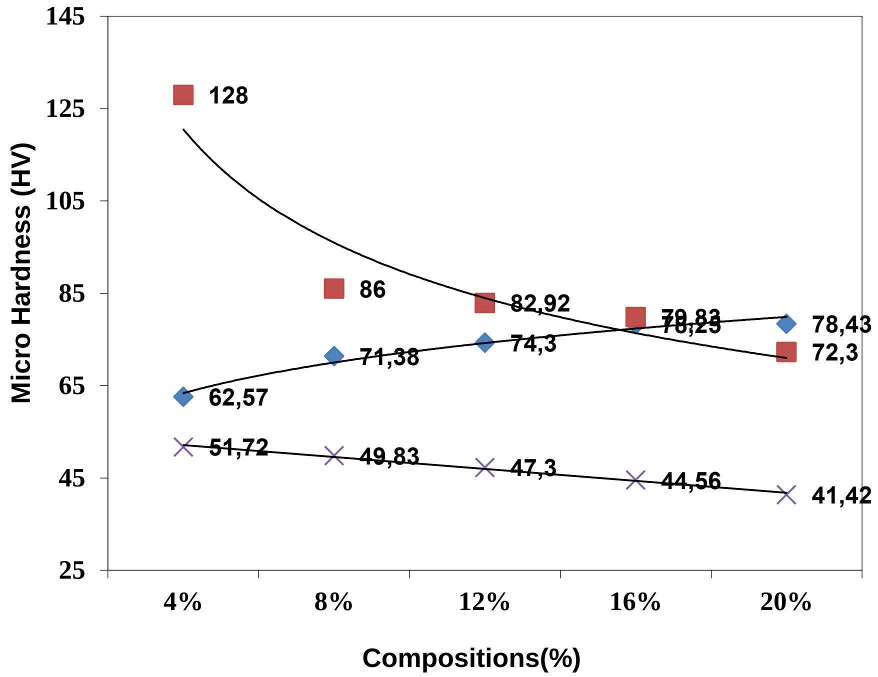

Figure 2. The micro hardness tests results

Investigation of the Production and Mechanical Properties of SiC-Reinforced Intermetallics Shear strength was applied to the produced samples. Due to the change in composition, the cutting strength decreased as the ratio of SiC increased. In the shear strength tests performed at three different temperatures, the highest strength was obtained in sintered samples at 1100°C. The lowest shear strength values were obtained at 1000°C.

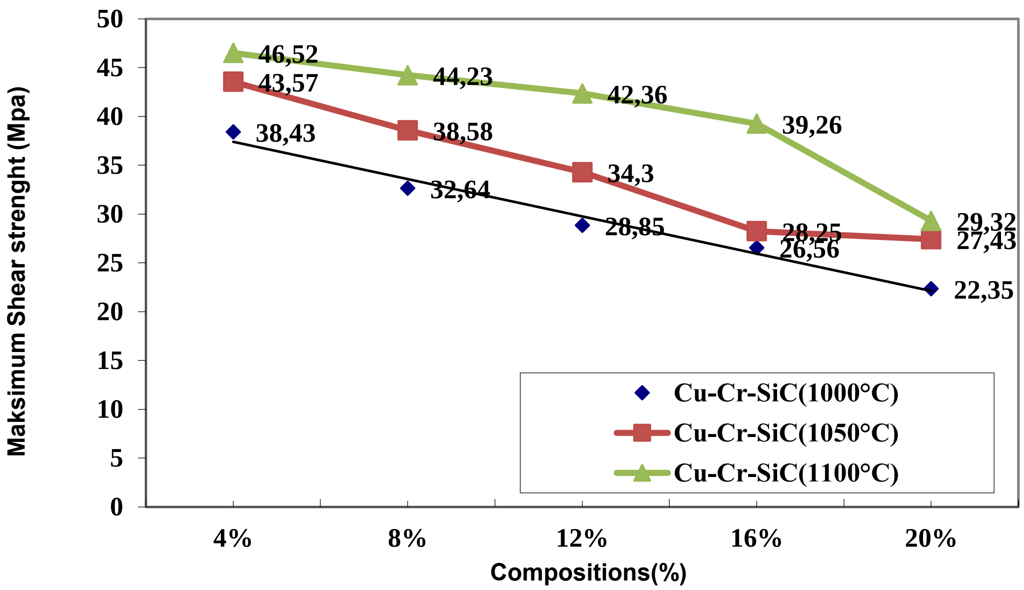

Figure 2. The Maximum shear strength tests results from sintered specimens.

Metallographic Analysis

The SEM analysis result of the metal matrix composite specimen obtained from Cu-Cr-%4SiC powders sintered at 1000 ºC is shown in Figure 4. Grain growth is observed, and a homogeneous structure and grain boundaries can be seen that the pores very smaller. These density and hardness values are confirmed.

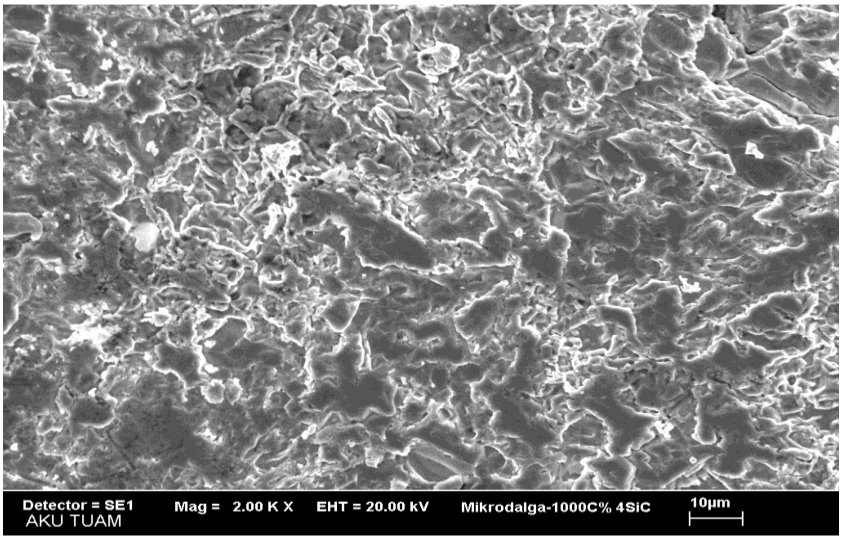

Figure 4. SEM view of Cu-Cr-4SiC composite 1000°C

The SEM analysis result of the metal matrix composite specimen obtained from Cu-Cr-%4 SiC powders sintered at 1050 ºC is shown in Figure 5. Grain growth is observed, and a homogeneous structure and grain boundaries can be seen that the pores are very smaller than Fig. 4. These density and hardness values are confirmed.

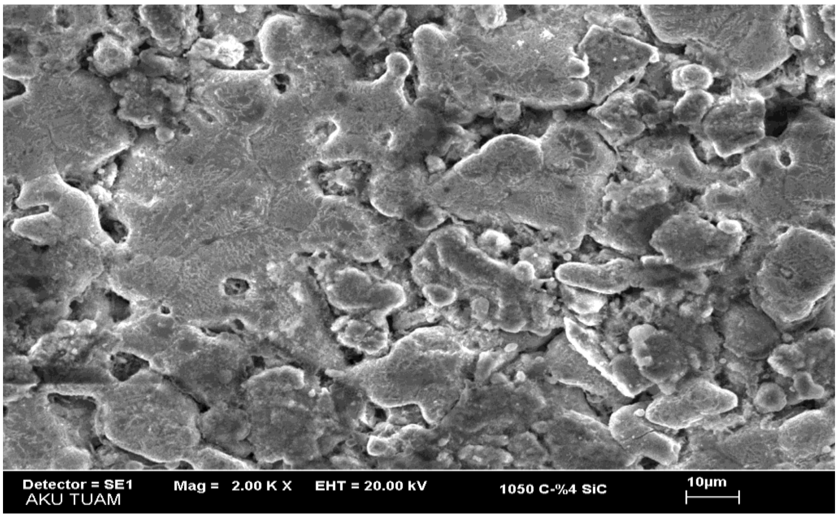

Figure 5. SEM view of Cu-Cr-4SiC composite 1050°C

The SEM analysis result of the metal matrix composite specimen obtained from Cu-Cr-%4 SiC powders sintered at 1100 ºC is shown in Figure 6. Grain growth is observed. It is not a homogeneous structure and grain boundaries can be seen that the pores very smaller than Fig. 5. These density and hardness values are confirmed.

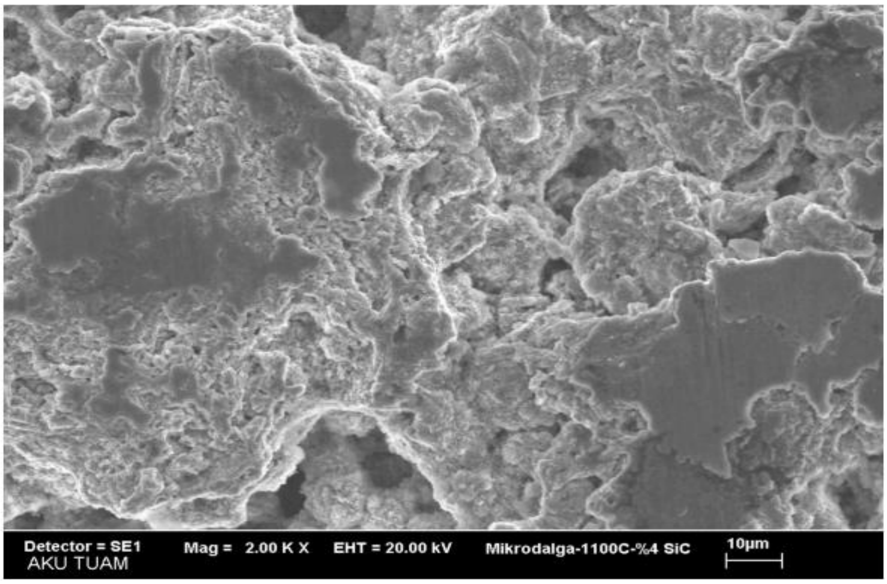

Figure 6. SEM view of Cu-Cr-4SiC composite 1100°C

X-Ray Diffraction Analysis

Fig. 7 presents the XRD analysis results of Cu-Cr composites at 1100°C. The Cu phase, 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 Cu-Cr composites. Fig. 6 shows the presence of Cu, Cr, Cu_2O, and CrCu phases in the fabricated ceramic-metal composites.

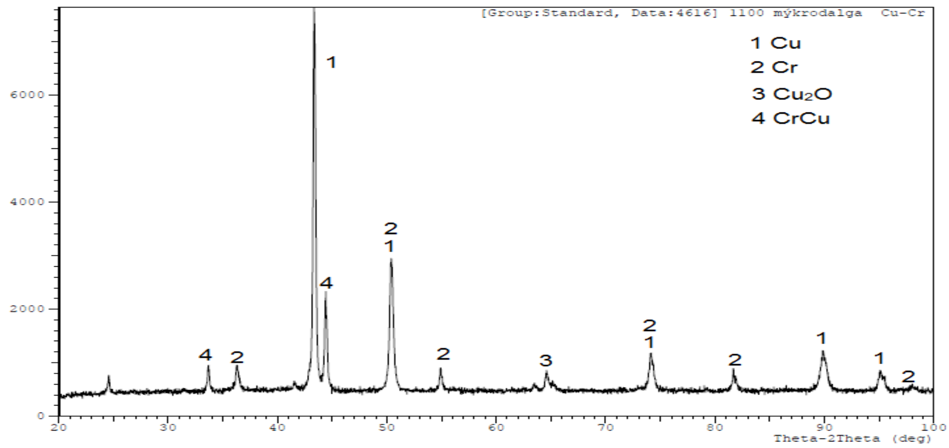

Figure 7. XRD analysis results of Cu-Cr composite at 1100°C

Fig. 8 presents the XRD analysis results of Cu-Cr-%4SiC composites at 1100°C. The Cu phase, 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 Cu-Cr-%4SiC composites. Fig.7 shows the presence of Cu, Cr, Cu_2O, CrCu, and SiC phases in the fabricated ceramic-metal composites.

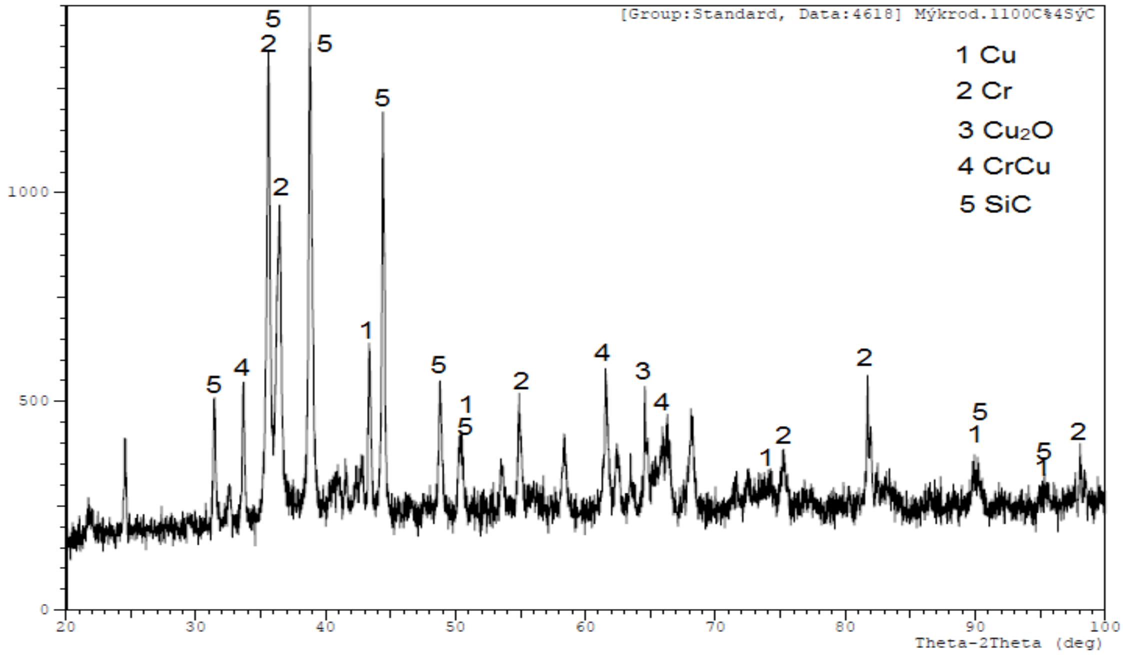

Figure 8. XRD analysis results of Cu-Cr-%4SiC composite at 1100°C

CONCLUSION

In this study, the mechanical properties of the material were improved by making ceramic contribution to the metal materials. The cost of energy in the production of energy materials was reduced by sintering the intermetallic materials in industrial microwave oven in a short time. In the samples produced, the microstructural grain growth occurred at a faster lowering temperature than in the conventional furnace.

The following results were concluded from the experimental findings:

The highest density in the composite made from Cu-Cr-%4SiC powders sintered at microwave furnace was obtained as 1100°C. The highest density sample was found as 6,016gr/cm^3 at 1000°C.

The highest micro hardness in Cu-Cr-%4SiC composite samples fabricated using powder metallurgy method was found as 128HV at 1000°C.

It was also found out for composition of Cu-Cr-%4SiC at 1000°C suggest that the best properties that specimens.

Intermetallic materials had difficulties in the production and shaping of intermetallic compounds. The improvement of the properties of these materials has been easy but expensive. It is thought that it will provide many advantages to be produced by microwave sintering method. It is known that mechanical properties of microwave sintered samples are better than conventional sintered samples. Using the microwave sintering method, energy savings of up to 60% have been achieved.

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