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Research Article

Seramik-Metal Kompozitlerde Ultrasonik Zayıflama ve Sertlik İlişkisinin Araştırılması

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Özet

Malzeme karakterizasyonunda ultrasonic dalgaların malzemelerden boyuna geçişleri sırasında kayma dalgaları sayesinde incelenen malzemenin mekanik ve fiziksel özellikleri hakkında elde edilen frekansta yer alan çok sayıda bilgiyi bulundururlar. Bu çalışmada, elde edilen dalga zayıflama katsayıları gibi bazı ultrasonik parametrelerin değişimini incelemek için metal matrisli kompozit numuneler üzerinde deneysel bir çalışma yapılmıştır. Bakır-silisyum karbür kompozitlerde elde edilen ultrasonik boyuna ve kayma zayıflama değerleri darbe-yankı tekniği ile 4 MHz frekansında ölçülmüştür. Üretilen numunelerin tamamı 1050ºC sıcaklıkta mikrodalga sinterleme tekniği ile sinterlenmiştir. Malzemede boyuna dalga ile kayma zayıflama değerlerinin numunedlerde sertliğin % SiC hacimsel yüzdeleri ile değişimleri ölçülmüştür. Elde edilen deneysel sonuçlar, mikroyapı belirlemede ultrasonik tahribatsız muayne yönteminde bir teknik geliştirmek için tartışılmış ve analiz edilmiştir. Ultrasonik dalgaların malzemelerden geçişleri ile incelenen malzemenin mekanik ve fiziksel özellikleri hakkında elde edilen frekansta yer alan çok sayıda bilgiyi içermektedir.

Bu çalışmada, Metal matrisli SiC katkılı kompozit numuneler üzerinde dalga zayıflama katsayıları gibi bazı ultrasonik parametrelerin değişimini incelemek için deneysel bir çalışma yapılmıştır. Üretilen Bakır-silisyum karbür kompozit numunelerde ultrasonik boyuna ve kayma zayıflama değerleri darbe-yankı tekniği ile 4 MHz frekansında ölçülmüştür. Boyuna ve kayma zayıflama değerlerinin ve sertliğin % SiC hacim yüzdeleri ile değişimleri belirlenmiştir. Elde edilen deneysel sonuçlar, mikroyapı belirlemede ultrasonik tahribatsız muayne yöntemini geliştirmek için tartışılmış ve analiz edilmiştir.

Anahtar Kelimeler: Ultrasonik hız, Seramik-metal, Kompozit, Sertlik

Investigation of Ultrasonic Attenuation and Hardness Relationship in [*]Ceramic-Metal Composites

Abstract

In material characterization, they contain a large amount of information at the frequency obtained about the mechanical and physical properties of the material under investigation, thanks to shear waves during the longitudinal passage of ultrasonic waves from materials.In this study, an experimental study was carried out on metal matrix composite samples to examine the variation of some ultrasonic parameters such as wave attenuation coefficients. Ultrasonic longitudinal and shear attenuation values obtained in copper-silicon carbide composites were measured at 4 MHz using the pulse-echo technique. All of the produced samples were sintered at 1050 ºC using microwave sintering technique. The variation of the shear attenuation values with the longitudinal wave in the material with the % SiC volumetric percentages of the hardness in the samples were measured. The experimental results obtained are discussed and analyzed to develop a technique in ultrasonic nondestructive testing for microstructure determination. It contains a large amount of information in the frequency obtained about the mechanical and physical properties of the material examined by the passage of ultrasonic waves through the materials.

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In this study, an experimental study was carried out to examine the variation of some ultrasonic parameters such as wave attenuation coefficients on metal matrix SiC doped composite samples. Ultrasonic longitudinal and shear attenuation values of produced copper-silicon carbide composite samples were measured at 4 MHz frequency by pulse-echo technique. Variations of longitudinal and shear attenuation values and hardness with % SiC volume percentages were determined. The experimental results obtained are discussed and analyzed to improve the ultrasonic nondestructive testing method for microstructure determination

Keywords: Ultrasonic attenuation, Ceramic-metal, Composite, Hardness

1. Introduction

Ultrasonic material characterization is based on statistical attributes of image texture or on estimations of physical properties of materials, particularly ultrasonic velocity, attenuation and backscatter (D'astous et al., 1986). In the material characterization area, the attenuation of ultrasonic waves is of great interest. When no scattering occurs at the grain boundary, the main sources of energy loss in solids are absorption, dislocation relaxation, and elastic hysteresis (Lemlikchi et al., 2017). While the ultrasound wave propagates in a solid environment, the term absorption is used for the average energy loss that occurs due to its direct interaction with the particles in the environment. This reduction event occurs due to the absorption and scattering properties of the solid and is called "attenuation" (Saniee et al., 1988). There is partial reflection of waves at each particle boundary and this reflection is seen in all directions due to the irregular shape of the particles. This is how the energy disappears from the waves, and the further away from the source, the less in intensity (Filipczynski et al., 1966). Ultrasonic absorption occurs in the presence of microscopic structural defects. When an ultrasound wave moves through an inhomogeneous material, its amplitude decreases. Attenuation refers to the loss of signal amplitude due to increasing the propagation distance. The coefficient of attenuation loss is defined as the ratio of two amplitudes and can be calculated by Equation (1). The loss is usually expressed in logarithmic units such as Neper or dB, where A_1 and A_2 are the first two consecutive amplitudes of the ultrasonic wave returning within the confines of the particles (Blitz & Simpson, 1984; Nagy, 2003).

$$\alpha=(1/d)20\log A_1/A_2 \qquad (1)$$

It is known that ultrasonic testing plays an important role in determining material characterization and quality. With the rapid advancement of science and technology, the need for lightweight yet superior materials for use in aerospace and automotive industries, medical, sports and other fields has increased rapidly. In order to obtain these superior properties, composite materials have been produced by developing systems consisting of different materials or phases that are combined by correcting each other's weaknesses. One of the most important ways to improve the properties of composites is the changes made with the added reinforcements (Podymova & Karabutov, 2017, Bindumadhavan et al., 2002; Trojanova et. al., 2004; Gür, 2001; Sarpün et. al.,2009;Yönetken, 2017; Yönetken, 2019; Bilici et al., 2019; Bilici et al., 2021).

Accordingly, in this study, Cu-SiC composites were produced by powder metallurgy technique by uniform distribution of SiC particles with four different volume percentages in the (Cu) metal matrix. By changing the volume percentages of the newly produced Cu-SiC composites, ultrasonic properties (attenuation values) after sintering were examined by using the ultrasonic test method. In addition, its mechanical properties (especially hardness values) were measured and the change with the constantly increasing SiC volume percentages added to the Cu matrix was observed.

Silicon carbide, which has many good properties such as good thermal conductivity and low friction, can be used as both structured and functional materials (Chen et al., 2003). SiC-containing ceramic metal composites have higher thermal properties and chemical stability (Somiya, 1991; Yönetken, 2019; Yönetken and Erol, 2020).

2. Experiments

2.1. Experimental systems and particle samples

produced composite used in this study, SiC reinforced Cu matrix composite samples were used. In the study, samples with four different SiC volume percentages were prepared (1%, 2%, 3%, 4% SiC). Sample compositions were prepared by mixing Cu-1% SiC, Cu-2% SiC, Cu-3% SiC, and Cu-4% SiC powders. Each of the samples obtained had a diameter of 15 mm and a thickness of approximately 5 mm. Samples were mixed homogenously for 24 hours in a mixer following the weighing. The thickness of the sample is important in order to examine the ultrasonic properties. It is undesirable for the sample to be too thick or too thin in ultrasound measurements in order to ensure that the signal sent to the sample progresses in the sample and reflects back. All the powders were pressed using a hydraulic press at a pressure of 305.9 kg/cm^2, then the cold pressed samples underwent sintering at 1050 °C for 30 min. in a microwave furnace using an Argon gas atmosphere.

2.2. Ultrasonic attenuation measurements

In ultrasonic measurement methods, there is a transducer that produces the ultrasound and another transducer that detects the produced ultrasound from the other end of the medium, and this situation is the same in every experimental system. In this study, we used the pulse-echo method, one of the ultrasonic measurement methods. In the pulse-echo method, a 4 MHz (Sonatest SLH4-10, T/R) transmitter/receiver longitudinal probe was used to measure ultrasonic longitudinal absorption and a 4 MHz (GE Inspection Technologies MB 4Y 66100541) transmitter/receiver transverse probe was used to measure ultrasonic transverse wave absorption. Liquid gel was used as a coupling fluid between the probes and the sample. Then, the image of the ultrasonic wave sent to the sample with the transmitter / receiver transducer was obtained with the front wall reflection, back wall reflection peaks, and echo peaks on the A-Scan screen. Measurements were attempted until the sharpest peak in the spectrum was obtained. The attenuation coefficient was calculated from he ratio of the amplitudes of the two consecutive reflected ultrasonic waves. This analysis was repeated six times for each compound and then averaged for an accurate measurement. The longitudinal and shear attenuation coefficients were calculated using Equation 1.

2.3. Hardness measurement

The measurement of hardness in produced composite samples is an important indicator of characterization. A METTEST-HT (Vickers) micro hardness tester was used for hardness measurements. During the measurement, the hardness test was carried out on the samples using Vickers hardness at 0.5 kg load. In addition, the hardness values obtained from eight different regions of each composite sample are given by taking the average.

3. Results and Discussion

In this study, the characterization of the produced ceramic metal composite samples by the ultrasound method was investigated. It is the determination of the longitudinal and shear attenuation values of the ultrasound in the sample, the changes in hardness, and the SiC volume percentages (Table 1). The longitudinal propagation of ultrasound waves, shear attenuation, hardness, and density behavior of Cu-SiC composite samples are given in Figure 1 and Figure 2.

Table 1.Sintering temperature, ultrasonic longitudinal and shear attenuation, hardness and density values of Cu-SiC composites.

Table 1. Sintering temperature, ultrasonic longitudinal and shear attenuation, hardness and density values of Cu-SiC composites.

Compositions	Temperature°C	Longitudinal Attenuation (dB/mm)	Shear Attenuation (dB/mm)	Hardness (0.05 HV)	Density(g/cm^3)
Saf Cu	1050	0,531	1,091	85,2	5,010
%1 SiC	1050	0,238	0,485	104	6,509
%2 SiC	1050	0,353	0,646	112	5,407
%3 SiC	1050	0,424	0,867	117,7	6,102
%4 SiC	1050	0,510	1,089	130,8	5,202

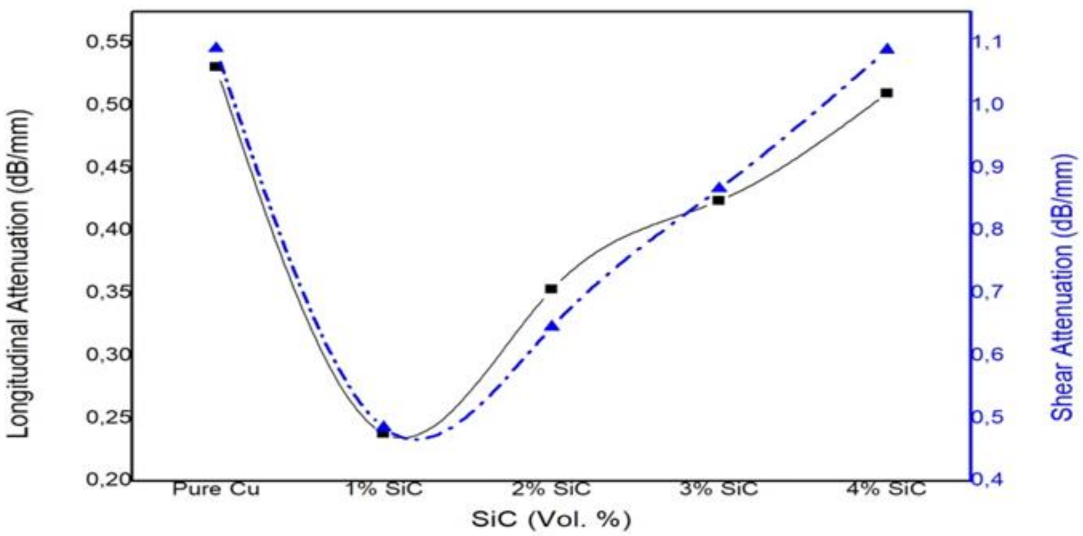


Figure 1. Variation in longitudinal and shear attenuation with volume fraction of SiC

The longitudinal and shear attenuation of ultrasound waves for the produced Pure Cu sample were measured as 0.531 dB/mm and 1.091 dB/mm, respectively. As seen in Figure 1, the ultrasonic longitudinal and shear attenuation in all samples increases with an increase in SiC content. At least two reflection peaks from the posterior surface must be able to be measured in order to make attenuation measurements. Therefore, if the sample is too thick, it will be difficult to observe the second background reflection in the spectrum due to the attenuation of the ultrasonic waves in the solid. If the sample is too thin, the attenuation to be measured at its amplitude cannot be determined precisely, as the ultrasonic wave will interact with the material very little. Therefore, the ultrasonic wave propagating inside the solid will pass through clusters instead of the millions of particles found in the composite. For this reason, scattering of an ultrasonic wave does not occur at each particle-particle interface rather than between particle clusters (Mylavarapu & Woldesenbet, 2008).

The increase in hardness observed in the graph (Figure 2.) increases the probability of ultrasonic wave-particle interaction. There is an increase in the attenuation of the ultrasonic wave return. Consequently, the wave-particle interaction is more likely to occur, so there is an increase in wave attenuation.

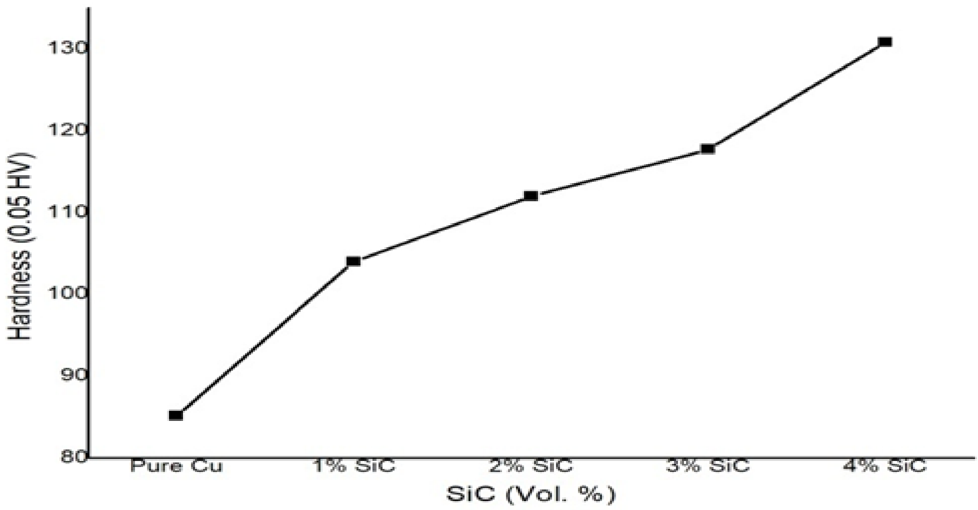
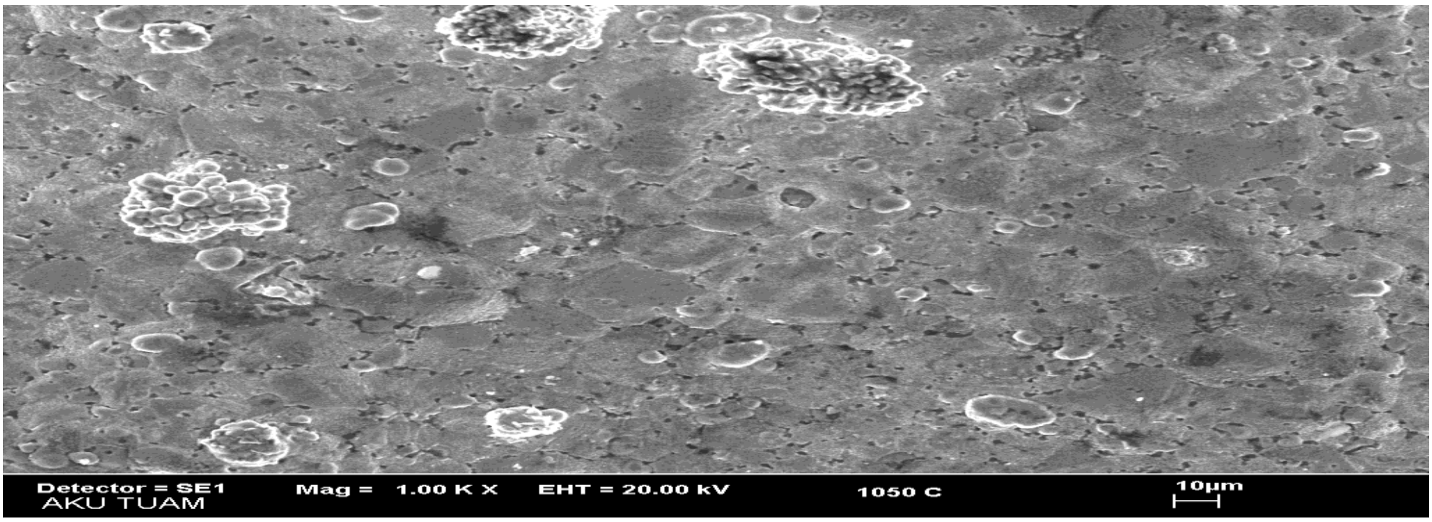
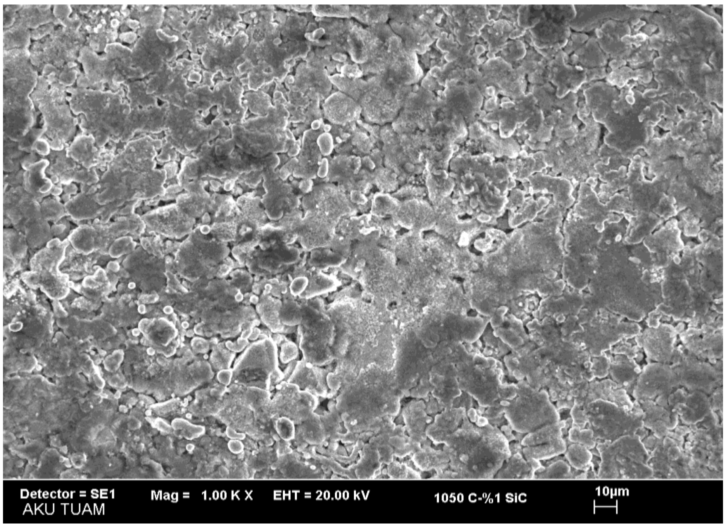


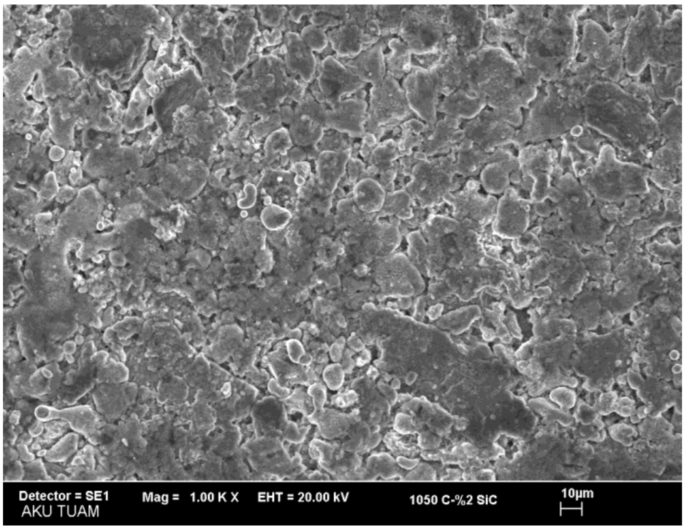
Figure 2. Variation in hardness with volume fraction of SiC

A ceramic additive was added in varying volume ratios (%SiC) to the produced ceramic metal composite samples. As the SiC ratio increased, the increase in the hardness of the material was measured. This increase was observed in the bonding between the grains, the porosity of the samples, the neck formation of the Cu matrix and grain coarsening. It shows that the porosity in the material microstructure is reduced and also that the sintering process is done well. Grain size, dislocation density, precipitates, etc. in the material microstructure. It has a strong influence on the hardness of materials, with almost no change in flexibility. SiC reinforcement content is an important factor controlling the strength of ceramic metal composites. It is known that for a given matrix alloy and its reinforcement, the yield and tensile strengths generally increase with increasing reinforcement content, and as a result, a similar increase in the hardness of the composite is expected.



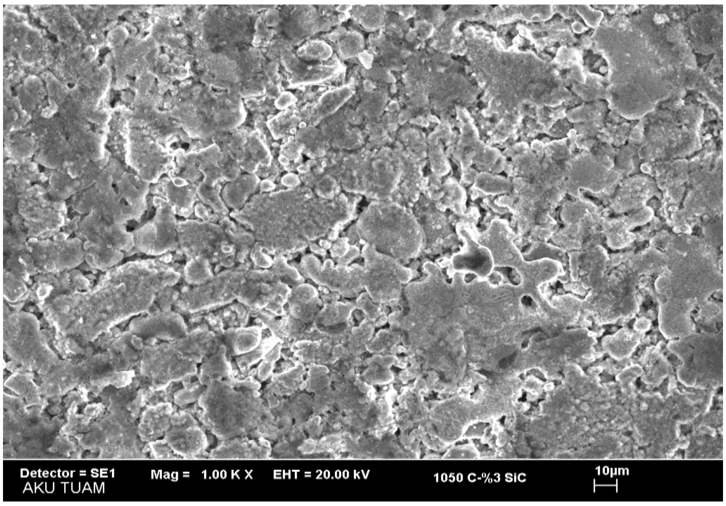
a)Cu (pure)1050 °C

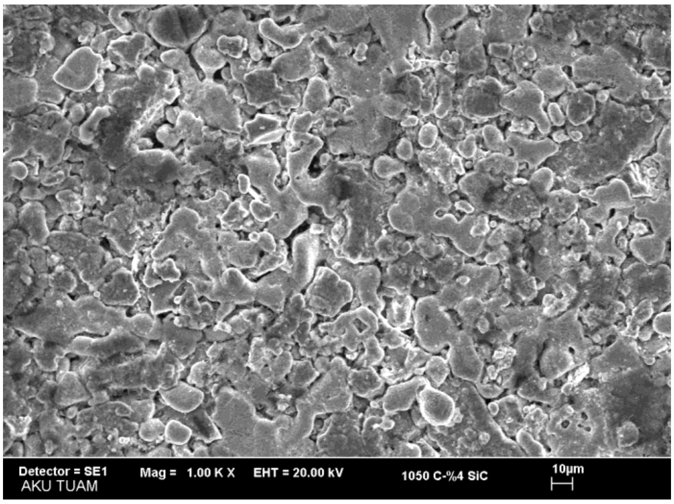




b) Cu-%1SiC 1050 °C

c) Cu-%2SiC 1050 °C



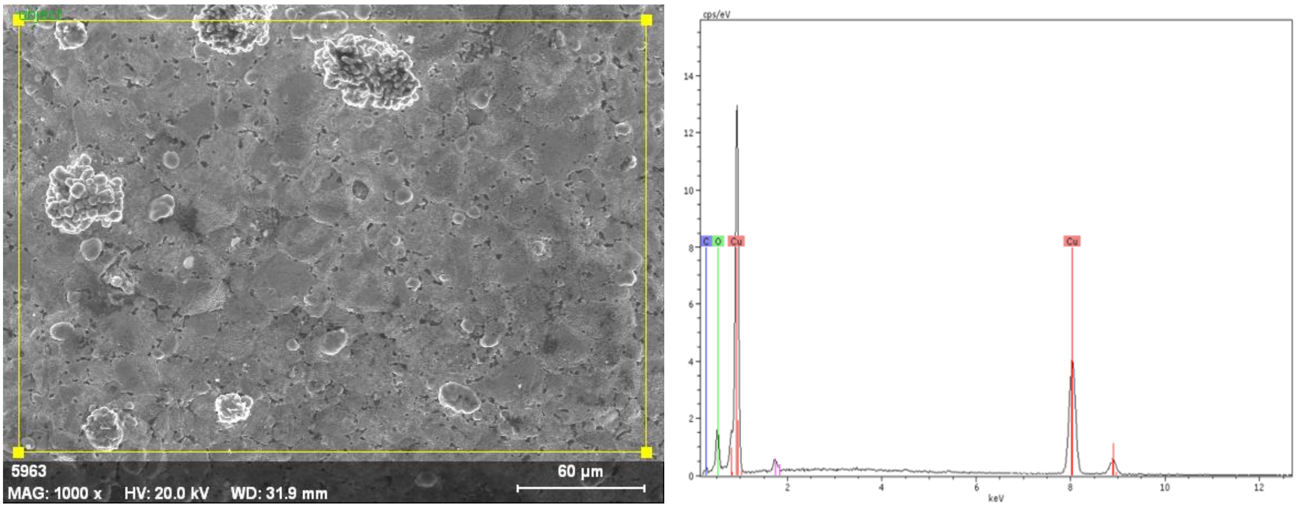


d) Cu-%3SiC 1050 °C

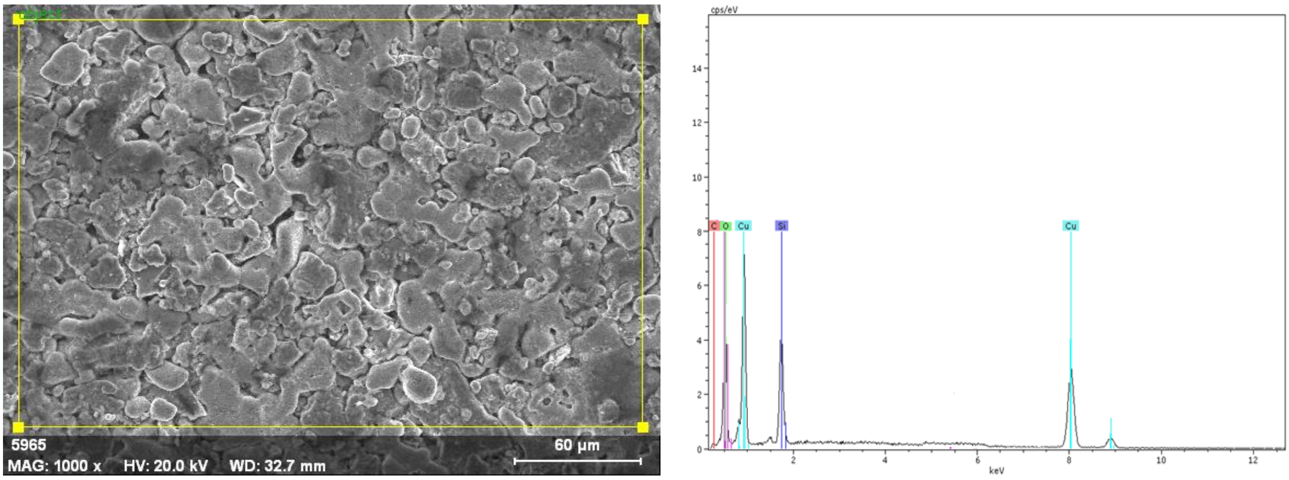
e) Cu-%4SiC 1050 °C

Fig.3. *SEM Photo Cu depod SiC composites1050 °C*

SEM picture of the composite produced by sintering from pure Cu powders at 1050 °C is given in Figure-3a. In the SEM picture of the sample, it is seen that the porosity is low and the grain glazes are evident from place to place. In other samples produced at the same temperature, it was observed that the porosity increased as SiC contribution increased, starting from Figure-3b to Figure-3e. As the SiC contribution to the produced sample composition increased, the hardness value increased. In Figure-3e, intergranular neck formation was observed in the sample image with the highest SiC contribution. It was determined that the sintering did not reach the final stage, therefore the porosity was higher than the other samples.



a) Cu (pure)



b) Cu-%4SiC

Fig.4. *EDX Analysis composites1050 °C*

Elemental field analysis (EDX) of pure copper is given in Figure-4a. Cu, O and C elements were determined according to the analysis result. Cu, Si, C and O elements were determined in the analysis made with the same method in the sample belonging to the Cu-%4SiC composite in Figure-4b. The elements determined in the composite samples of the compositions formed according to the obtained EDX analysis confirmed the study.

4. Conclusion

In the study, the ultrasonic pulse-echo technique was used effectively for the characterization of metal-matrix SiC-doped composite properties by a non-destructive testing method. Composite materials containing 1-2-3-4% SiC with Cu matrix reinforced with ceramic powders were characterized using ultrasonic techniques. In addition, the effect of the volume percentages of the composition on the ultrasonic properties and the change effects on the hardness of the materials were determined in the study. An increase in both the ultrasonic attenuation coefficient and hardness was observed with the increase of the volume percentages in the samples that were heat treated at 1050°C in the microwave oven. The increase in the SiC additive ratio increased the material porosity and led to a weakening of the ultrasound propagation.

The produced composition is a matrix alloy of Cu and SiC reinforcement. It has been shown that the yield and tensile strengths increase with increasing SiC reinforcement content in general. Therefore, a similar increase in the hardness of the produced samples was obtained. The relationship between ultrasonic properties and mechanical properties of the produced Cu-SiC composite samples has been shown. It has been observed that SiC reinforced Cu-SiC composites exhibit better mechanical properties than pure copper materials.

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