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The Production and Investigation of HEA Reinforced Copper Based Composite

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The high entropy alloys (HEA) are generally high-quality materials consist of elements with different properties. In these types of materials, in general, alloying is made with other elements that have a smaller amount in addition to atomically high proportion elements such as copper, aluminum or iron. The amount of entropy formed according to the diversity of the elements they contain determines the entropy class of the material. In this case, species less than 1 are called low entropy materials, between 1 and 1.5 are called medium entropy, while higher than 1.5 are called high entropy alloys. Due to their high mechanical properties, HEA materials are a good alternative to existing types of materials. In this study, copper matrix and metal matrix composite were synthesized of CoFeNiAlTiCr alloy with high properties. The obtained composite was examined by different analyzing methods and reported.

Keywords: High entropy alloy, metal matris composite, copper matrix

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1. Introduction

Material technology has developed very rapidly during history. In 2004, with a scientific research article, high entropy alloys having a different design entered in the literature. Later, interesting researches were conducted in many areas[1]. These materials are synthesized to have at least 5 elements and exhibit superior properties of their components [2, 3]. This type of alloy, which is generally synthesized as equimolar, exhibits high configurational entropy due to the structure and settlement possibilities of atoms. Today, there is a configurational entropy of all impure metallic materials. In the literature, this amount is generally called low entropy if it is less than 1 and medium entropy if it is between 1 and 1.5 high entropy is accepted when values of 1.5 or higher are obtained [4-6]. In general, the alloy design has one or two principal elements. The main characteristics of the structure include the properties of these materials. Additional elements which are added to the alloy and are not less than 5% atomically allow further development of the structural property. Materials with these superior properties are generally used singly [7]. They are very similar to the mechanical design of composite structures and the design of high entropy alloys [8, 9]. But the biggest difference between them is the homogeneity pattern in their microstructures. Naturally, the product character design is very different due to differences in composite structures at the macro level. Copper is generally a kind of metal which conducts heat and electricity very well and can be considered as a relatively good strength.

In this study, a new metal matrix composite was produced by using CoFeNiAlTiCr high entropy alloy, which we synthesized previously in pure copper matrix as reinforcement material, and the results were characterized by using different analyses.

2. Experimental details

In the experimental part Co,Fe,Ni,$Al_{0.4}$,$Ti_{0.6}$,$Cr_{0.5}$ high entropy alloys were synthesized by us earlier. The CoFeNiAlTiCr HEA was mixed with high purity copper (99.9%) metal and zinc stearate at 5%, 10%, 20% and 25% ratios. In argon medium, the mixture was placed into the bulk container with a ball-to-powder (BPP) ratio of 15: 1 and ø12mm diameter steel balls. The powder mixture was milled using a Retsch PM 100 brand apparatus (Figure 1.).

Fig.1: Compacted composite sample.

The mill was operated for 10min mechanical mixing at 250 RPM. After mixing process the samples were pressed with pellet mould. The obtained samples, SEM, DTA, TGA and XRD measurements were taken and results we presented in discussion section

3. Results and discussion:

The obtained samples were prepared for analyses. The differential thermal analysis (DTA) and TGA measurements were made by using a Shimadzu TA-60 WS to obtain the characteristic of phase structure. The DTA results are presented in Figure 2-5.

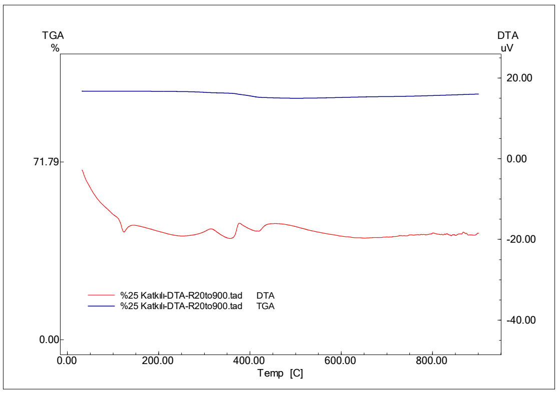

Fig.2: DTA and TGA curves for 5% composite

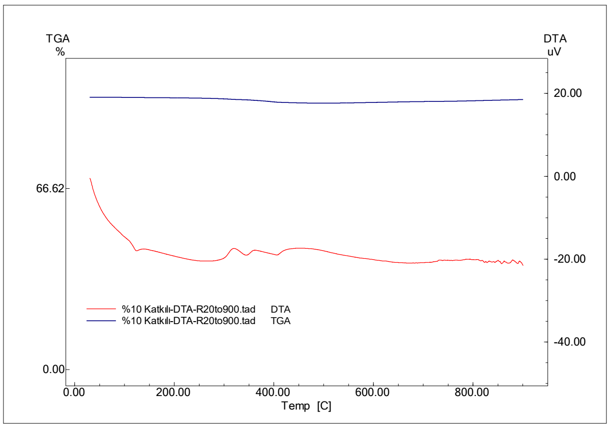

Fig.3: DTA and TGA curves for 10% composite

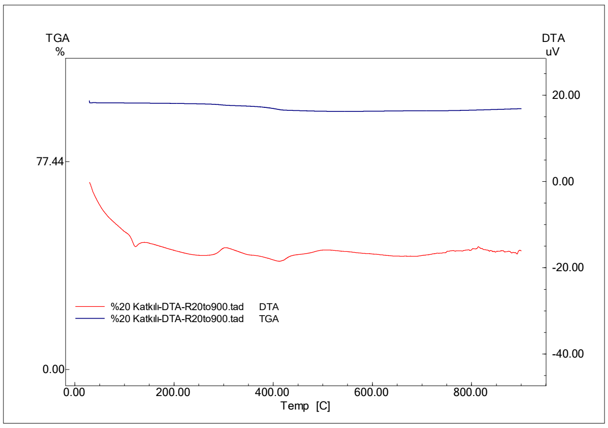

Fig.4: DTA and TGA curves for 20% composite

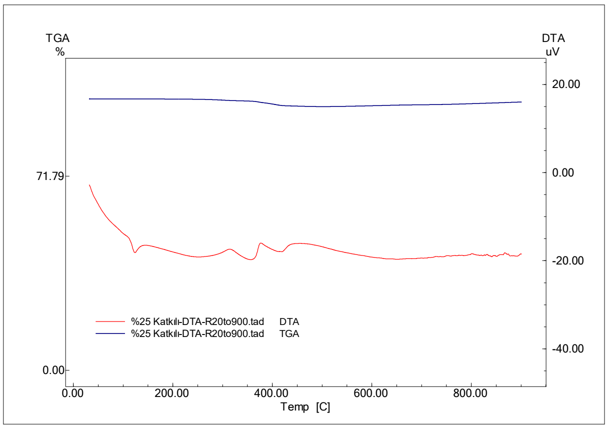

Fig.5: DTA and TGA curves for 25% composite

In general perspective, with the HEA increase in composite structure, there is a decrease in the affinity of copper to oxygen. Furthermore, the increase in HEA ratio, decreased oxidation of the copper matrix was observed in the samples. Also It was seen that zinc straters started to evaporate before reaching 200 degrees. Around 700 °C decomposition was seen as jerky character in DTA curve. Generally for TGA curves an mass loss were recorded in same temperature range around 400°C. The phase analysis of the alloys was carried out by XRD on a Rigaku Xray diffractometer using CuKα radiation at room temperature at a scan rate of 5 deg./min. The XRD diffractions were presented in Figures 6-9.

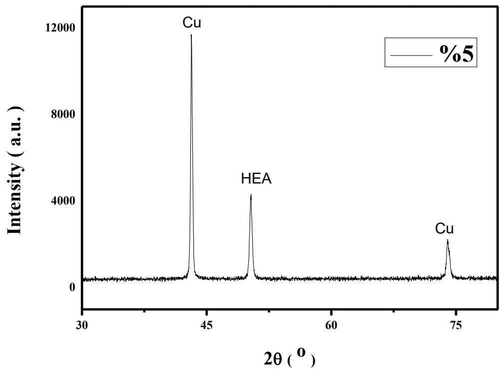

Fig.6: XRD pattern for 5% composite

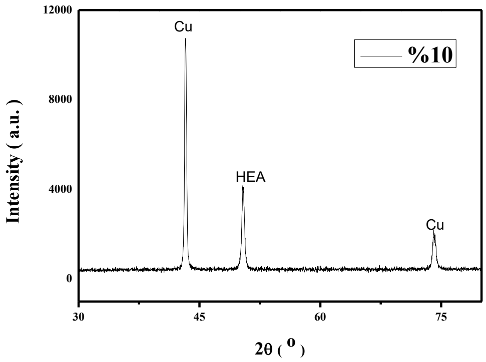

Fig.7: XRD pattern for 10% composite

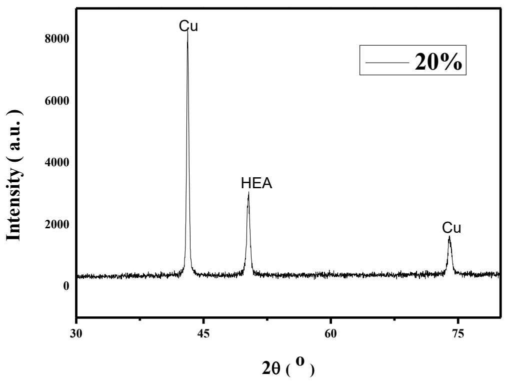

Fig.8: XRD pattern for 20% composite

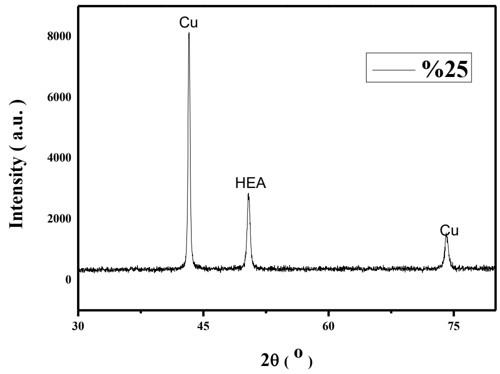

Fig.9: XRD pattern for 25% composite

In all XRD pattern generally exhibit same peaks. HEA peak clearly seems in pattern with lower density than Cu peak. Peak intensities decreased with increasing in the HEA reinforcement ratio. This is thought to be due to the mechanical alloying of HEAs. Because the HEA structures obtained at the end of 96 hours of grinding are nano-sized and semi-crystalline. After addition of copper to the matrix and sintering, crystallization of HEAs occurred but this crystallization was not sufficient. This may be attributed to the increased amount of HEA as the reason for the decrease in the intensity of the peaks in the composite.

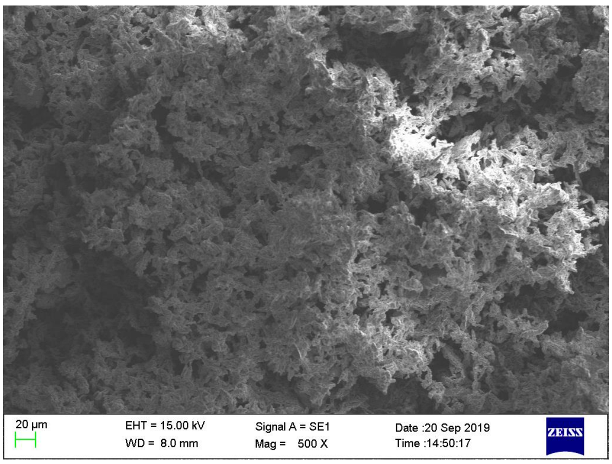

Fig.10: SEM images for 5% composite

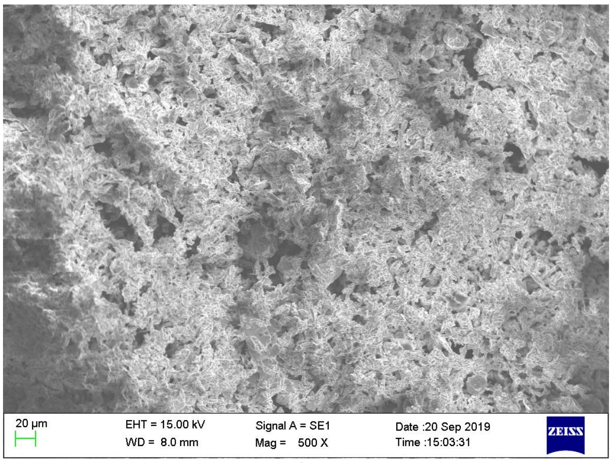

Fig.11: SEM images for 10% composite

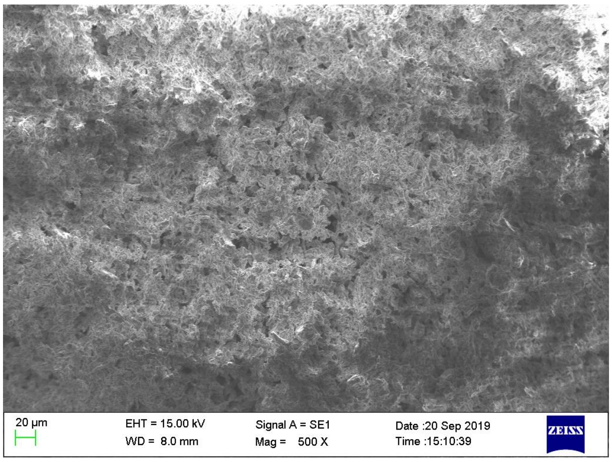

Fig.12: SEM images for 20% composite

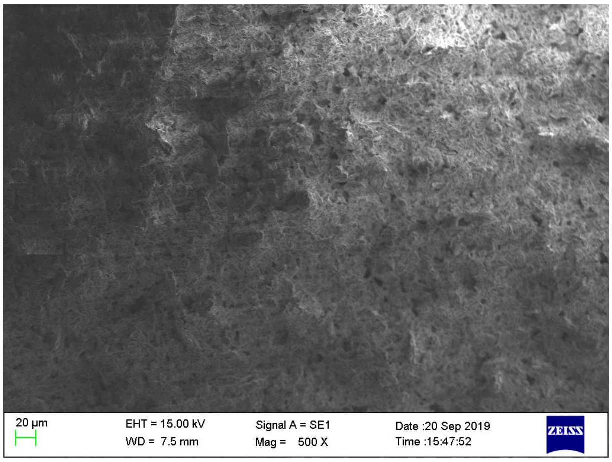

Fig.13: SEM images for 25% composite

Figure 10-13 shows the SEM image of the samples. Increasing amount of HEA decreases the amount of porosity in the structure. The nano-level HEAs into the copper are embedded in the copper matrix by the effect of milling, or in other words, are surrounded by copper particles. With the increased amount of HEA, more HEAs begin to settle in the pores of the composite as well as be embedded in the matrix. For this reason, it is seen from the SEM images that the amount of HEA and the decrease in the amount of pore decreased. As the amount of HEA increased to 25%, the diameter of the pores was decreased as well as the amount of pores decreased. The irregular shape of the particles visible in the SEM images may be related to the grinding process during the production of the composite. Due to the ball impulses, the shape of the copper particles in the spherical form has turned into an irregular form and there has been a slight decrease in particle size.

Conclusions

High entropy alloys are new promised materials regarding conventional materials. High new properties exhibit with multi elements in alloy. In our study the CoFeNiAlTiCr were synthesized and used as reinforced material for copper matrix in composite. The HEA was added in different fractions to composition. The obtained samples were analyzed with different characterization techniques devices and results were presented detailed. Increased amount of HEA and decreases in the intensity of XRD peaks were observed. This indicates that the structure causes changes in crystallinity. It also changed the amount and type of porosity of the composite.

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