The 56th International October Conference on Mining and Metallurgy
22-25 October 2025, Bor Lake, Bor, Serbia
www.ioc.tfbor.bg.ac.rs

DOI: 10.5937/IOC25375R *Original scientific paper*

INFLUENCE OF THE HEAT TREATMENT ON THE STRUCTURAL PARAMETERS OF THE CuCrZr-TiB2 ALLOY

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Abstract

Powder metallurgy (PM) is used for the CuCrZr-TiB_2 alloy synthesis by employing mechanical alloying and hot pressing techniques. Powder mixture containing prealloyed CuCrZr powder, 7 wt.% Ti, and 3.2 wt.% B was firstly homogenized, and then mechanically alloyed (MA) for 27 hours. MA powders were hot pressed (HP) in protective atmosphere at temperature of 950 °C, with applied pressure of 45 MPa, and duration of 2.5 hours. Heat treatment (HT) of HP CuCrZr-TiB2 alloy was performed in two steps: (1) solution annealing (SA) at 1000 °C for 5 hours, and (2) age hardening (AH) at 470 °C for 3 hours. Changes in the structural parameters of the MA powders, and obtained compacts (HP, HT) were investigated by X-ray diffraction. Williamson-Hall equation was applied for calculation of the crystallite sizes (D, nm), lattice parameter (nm), and lattice strain (ε, %). The results show that heat treatment has significant influence on the structural parameters. After each step of HT, crystallite size and lattice strain decrease compared to HP samples owing to more homogeneous distribution of TiB_2, precipitate formation, and consequently restriction of the large grains recrystallization. Heat treatment, as well as structural parameters exhibit great influence on the mechanical properties of CuCrZr alloy. Therefore, these results indicate relation between specific heat treatment parameters, and structural parameters of the CuCrZr alloy, which may contribute to the future design of CuCrZr alloy with improved mechanical and physical properties.

***Keywords**: CuCrZr alloy; structural parameters; heat treatment; powder metallurgy*

1. INTRODUCTION

CuCrZr alloys have emerged as a prime candidate for applications in modern industry where excellent electrical and thermal conductivity, high thermal stability, and high strength and hardness are irreplaceable properties [1]. In order for CuCrZr alloys to be a good fit in above mentioned high-performance applications, the relationship between structural parameters and mechanical properties is crucial. Structural parameters such as grain size, dislocation density, and the morphology of precipitated phases play a determining role in their mechanical behavior [2]. Fine-grained structure, achieved through controlled thermo-mechanical processing, improves yield strength due to grain boundary strengthening, while also enhancing fatigue resistance [3].

The high strength of CuCrZr alloys comes from the formation of nanoscale Cr-rich and Zr-rich precipitates during aging and particle-dispersion strengthening mechanisms [4]. These particles block dislocation movement, increasing strength without significantly reducing electrical conductivity, thanks to the limited solubility of Cr and Zr in the copper matrix [5]. As the alloy ages, the solid solution breaks down into fine, evenly distributed phases that improve mechanical

properties while keeping conductivity high [6]. Although there is usually a tradeoff between strength and conductivity, CuCrZr alloys are known for maintaining a good balance between the two [7]. Therefore, optimizing the heat treatment becomes essential in order to achieve this favorable balance. Extensive research has been conducted examining mechanical and electrical properties, as well as the microstructure, of the heat treated alloy.

The aim of this study is to determine the effect that heat treatment parameters on the structural parameters of the reinforced CuCrZr alloy. By determining such relation, it can provide a potential for future design and cost-effective manufacturing of the reinforced CuCrZr alloys with improved mechanical properties.

2. EXPERIMENTAL

Prealloyed CuCrZr powder, with 7wt.% Ti, and 3.2wt.% B powders were homogenized, and then mechanically alloyed (MA) for 27 hours in the high-energy ball mill – shaker mill, in argon inert atmosphere. Hot pressing (HP) of the MA powders was done in protective argon atmosphere, at temperature of 950 ℃, with 45 MPa applied pressure, and 2.5 hours duration. Heat treatment (HT) of HP CuCrZr-TiB_2 alloy contained solution annealing (SA) at 1000 ℃ for 5 hours, and age hardening (AH) at 470 ℃ for 3 hours. Structural parameters of the MA powders, and obtained compacts (after HP, and HT) were investigated by X-ray diffraction using Rigaku Ultima IV. PDXL software was used to calculate structural parameters according to Williamson-Hall analysis: crystallite sizes (D, nm), lattice parameter (nm), and lattice strain (ε, %).

3. RESULTS AND DISCUSION

Structural and phase analysis were investigated using XRD. The obtained XRD pattern (Figure 1) of the powder after mechanical alloying identified presence of the elemental powders Cu and Ti, while powders B, Cr and Zr were not detected due to instrumental limitation. Furthermore, in Figure 1 all XRD patterns of compacts CuCrZr-TiB_2 (HP), CuCrZr-TiB_2 (SA), and CuCrZr-TiB_2 (SA-AH) indicate in situ formation of the TiB_2reinforcing particles and CuZr phase.

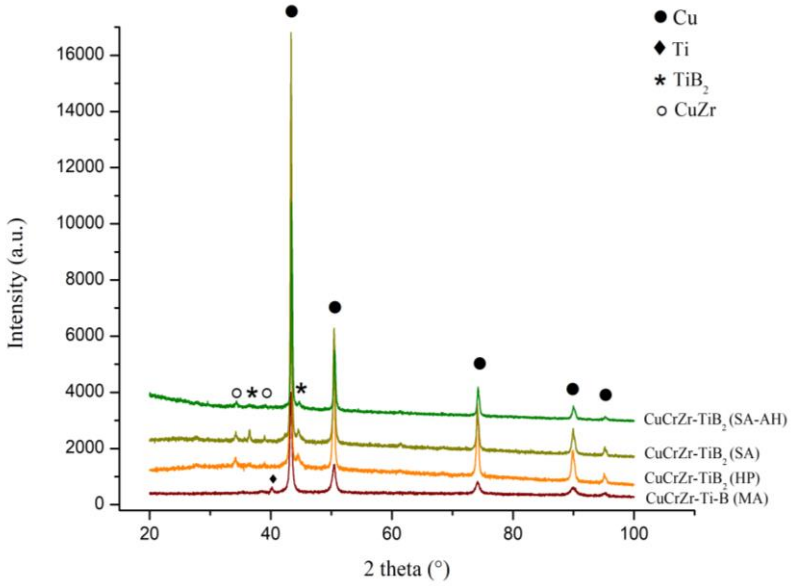

Figure 1. XRD patterns of the powders CuCrZr-Ti-B (MA), and CuCrZr-TiB_2 (HP), CuCrZr-TiB_2 (SA), and CuCrZr-TiB_2 (SA-AH) compacts.

Structural parameters, given in Table 1, were calculated using Williamson-Hall analysis. It can be observed that value of lattice parameter of non-treated CuCrZr powder is lower compared to MA CuCrZr-Ti-B powders, while crystallite size increased as a consequence of the high-energy collisions between ball-powders-ball and ball-powders-wall mill, as well as changes in particles'

shape. After hot pressing, the in situ formation of the TiB_2 particles was detected and drastic changes may be noted regarding crystallite size enlargement. Also, lattice parameter and strain slightly increased. During applied heat treatment, solid solution is formed, then solute atoms precipitate out of the solid solution (after aging) leading to a formation of new phases. These phenomena strongly affect the structural parameters of the copper matrix as can be seen in Table 1. After solution annealing significant decrease of the lattice parameter and crystallite size values was recorded, while lattice strain remains almost the same. This trend continued after age hardening, with harsh decline of lattice strain owing to grain recrystallization of the Cu matrix.

Table 1. Structural parameters of Cu and CuCrZr starting and MA powders.

	Lattice parameter, a [A]	Crystallite size, D [nm]	Lattice strain, ε [%]
CuCrZr	3.6276	66.7	0.10
CuCrZr-Ti-B (MA)	3.6201	120	0.12
CuCrZr-TiB_2 (HP)	3.6213	2275	0.31
CuCrZr-TiB_2 (SA)	3.6207	1259	0.29
CuCrZr-TiB_2 (SA-AH)	3.6139	289	0.07

Dislocation density values, calculated by using obtained values of the structural parameters [4], show that during heat treatment dislocation density increased from $0.33*10^{16}$ m^{-2} up to $1.24*10^{16}$ m^{-2}. These results confirm improvement of the CuCrZr-TiB_2 alloys' mechanical properties after heat treatment.

4. CONCLUSION

Influence of the applied heat treatment on the structural parameters of the reinforced CuCrZr alloy was investigated. XRD analysis exhibited in situ formation of the reinforcing particles (TiB_2) during hot pressing at 950 ℃. Heat treatment included solution annealing at 1000 ℃, and age hardening at 470 ℃. It was shown that heat treatment has great effect on the structural parameters of CuCrZr- TiB_2 alloy, leading to an increase in dislocation density and consequently improvement of its mechanical properties.

ACKNOWLEDGEMENTS

This work was funded by the Ministry of Science, Technological Development and Innovations of the Republic of Serbia (Contract No. 451-03-136/2025-03/200017) and by the Science Fund of the Republic of Serbia, Grant No. 7365, Development of dispersion-strengthened metal-based materials for applications in fusion reactor - DisSFusionMat.

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