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CHARACTERIZATION OF ALLOYS CuAlAu0.5

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Abstract

Phase equilibria of alloys CuAlAu0.5 was examined using optical microscopy (LOM), scanning electron microscopy with energy dispersive spectroscopy (SEM-EDS) and differential thermal analysis (DTA) methods. Based on the structural analysis of the examined alloys the existence of all expected phases was confirmed: solid solutions based on copper, aluminum and gold (Cu, Al, Au) and β phase. The characteristic temperatures of phase transformations of alloys were determined too. By measuring the hardness of the alloys, it was determined that the highest values of hardness were measured in alloys whose composition includes the β phase.

***Keywords**: CuAlAu0.5 alloys, characterization, martensite structure*

1. INTRODUCTION

Shape memory alloys include special materials that are characterized by two unique properties, the phenomenon of shape memory and pseudoelasticity. [1] It is these characteristics that have made these materials interesting for research for several decades. The motive for testing these materials is not purely academic in nature, but it is also the possibility of their application in technology, electronics, energy, medicine, bioengineering, space technology, etc. Alloys with a shape memory effect belong to a group of modern materials known as smart materials. It is characteristic for these materials to react to the influence of the environment, i.e., depending on the change of external conditions, there is a change in the properties of the material (mechanical, electrical, structural) [2]. In the last few years, due to high technical - technological development and market needs, primarily in the automotive and oil industries and robotics [3], there is a need for alloys that remember shape with high temperatures of phase transformations. It is characteristic of these alloys that the temperature of the beginning of the transformation of martensite into the initial phase is above 120^{o}C under stress - free conditions. [4] The most important and well-known alloys that show the shape memory effect are alloys based on nickel and titanium, as well as based on copper. Copper-based alloys are cheaper and can be produced in a simpler and more economical way, which, with appropriate thermal, mechanical, etc. properties, makes it suitable for application in engineering, energy, space technology, medicine, bioengineering, etc. [5] Today, the alloys of the Cu-Zn-Al and Cu-Al-Ni systems are the most widely used, but numerous studies indicate that intensive work is being done on the production and use of other copper-based alloys and a number of other elements.

2. EXPERIMENTAL

For experimental investigations in the concentration range of the Cu-Al-Au, the cross section with a constant gold content Au = 50 at% was selected. As-cast alloys were used in all tests. All samples were prepared by inductive melting of pure metals in a protective argon atmosphere. The total weight loss of the prepared ingots was less than 1% by weight. The compositions and masses of the tested alloys are given in Table 1. The following methods were used for characterization of the alloys CuAlAu0.5: optical microscopy (LOM), scanning electron microscopy with energy dispersive spectroscopy analysis (SEM-EDS), differential thermal analysis (DTA), measurement of microhardness and Vickers hardness and electrical conductivity measurement.

Table 1 - Composition and mass of tested alloys

Alloy	X_{Cu}	X_{Al}	X_{Au}	m_{Cu} (g)	m_{Al} (g)	m_{Au} (g)
Alloy 1	0.3	0.2	0.5	0.4697	0.1329	2.4273
Alloy 2	0.35	0.15	0.5	0.5400	0.0982	2.3917

The optical microscopy was used a Reichert MeF2 microscope with a maximum magnification of up to 500 times. SEM-EDS analysis was performed on a scanning electron microscope Sem Tescan Vega TS 5136MM (resolution 3nm at 20kV and maximum magnification up to 100000 times), with an energy dispersive spectroscope brand Bruker. DTA tests were performed on a device for simultaneous thermal analysis of materials Netzsch STA 449F1 Jupiter operating in the temperature range from -150^{o}C to 2400 ^{o}C and heating rate from 0.001 K/min to 50 K/min. DTA measurements were performed in an argon atmosphere with samples weighing up to 50 mg, at a constant heating and cooling rate of 10^{o}C/min. Al_2O_3 was used as a reference material. The hardness of the samples was determined using the standard Vickers method.

3. RESULTS AND DISCUSSION

SEM photographs of the tested samples of the alloys CuAlAu0.5 are shown in Figures 1 and 2. For the investigated alloys the presence of β phase was confirmed. The surface of the investigated alloys given in Figures 3 and 4, is corroded by imperial water. The microstructure of the alloy 1, composed of $Cu_{30}Al_{20}Au_{50}$, is characterized by the existence of polygonal, coarse β-phase grains in which a martensite structure is just emerging. In the alloy 2, composition $Cu_{35}Al_{15}Au_{50}$, the martensite structure is well developed, which is expected considering that the composition of this alloy is in the region of the β phase. Determinations of temperatures of phase transformations in the alloys CuAlAu0.5 were performed by DTA. After homogenization, the tested samples were heated and cooled with a heating and cooling rate of 10^{o}C/min. Onset was determined when determining the characteristic phase transformation temperatures, while peaks were taken for liquidus and temperatures of other phase transformations. The DTA heating and cooling curves of selected samples of the investigated alloys are shown in Figures 5 and 6, respectively.

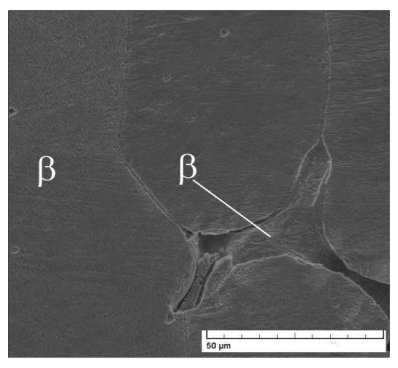


Figure 1. SEM of alloy 1 - $Cu_{30}Al_{20}Au_{50}$

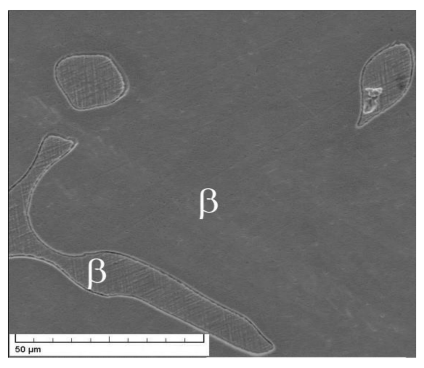


Figure 2. SEM of alloy 2 - $Cu_{35}Al_{15}Au_{50}$

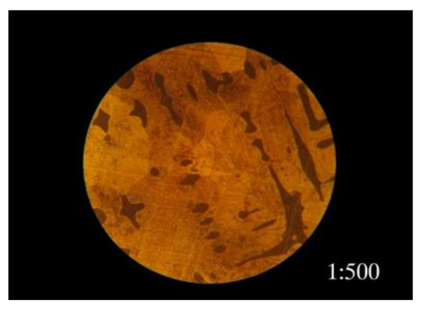


Figure 3. LOM for alloy 1 - $Cu_{30}Al_{20}Au_{50}$

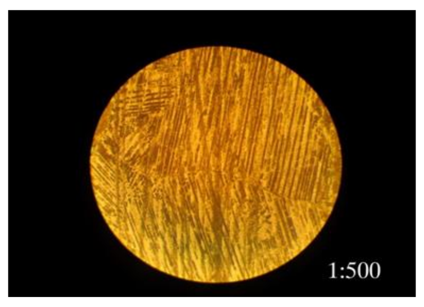
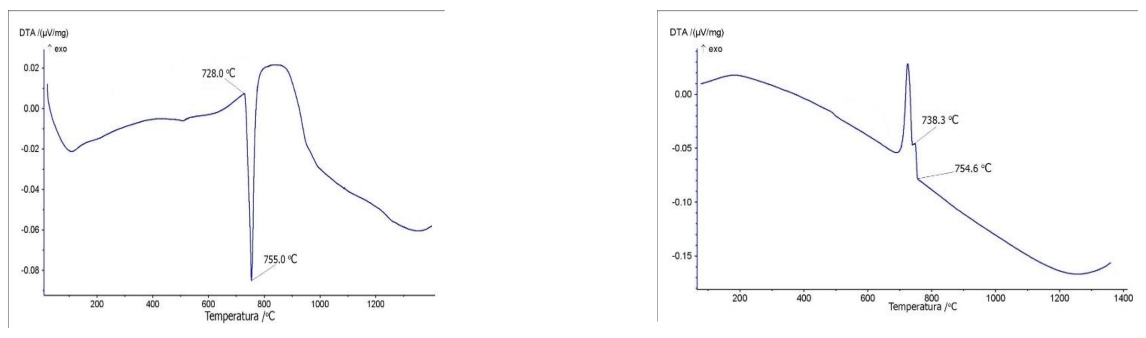
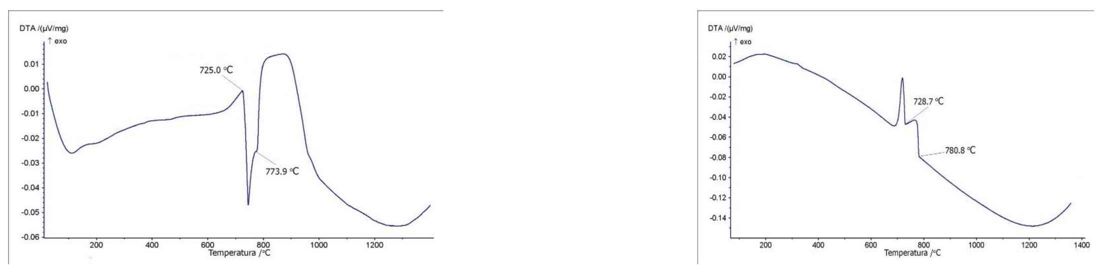


Figure 4. LOM for alloy 2 - $Cu_{35}Al_{15}Au_{50}$



a) b)

Figure 5. DTA curves for alloy 1: a) heating; b) cooling



a) b)

Figure 6. DTA curves for alloy 2: a) heating; b) cooling

The results of measuring the hardness of the investigated alloys are given in Table 2. It can be noticed that between the measured hardness of alloys 1 and 2, the difference is almost insignificant, which is expected because the compositions of these alloys are very similar. The load used in measuring the microhardness of the samples of the alloys was 100 g. The obtained measurement results are presented in Table 3.

Table 2 - Results of hardness measurements

Alloy	Chemical composition	HV10
Alloy 1	$Cu_{30}Al_{20}Au_{50}$	174
Alloy 2	$Cu_{35}Al_{15}Au_{50}$	164

The measured values of electrical conductivity of alloys 1 and 2 in Table 4, do not differ, which is in accordance with the compositions of these alloys.

Table 3 - Results of microhardness measurements

Alloy	Chemical composition	HV0.1
Alloy 1	$Cu_{30}Al_{20}Au_{50}$	267
Alloy 2	$Cu_{35}Al_{15}Au_{50}$	149

Table 4 - Results of electrical conductivity measurements

Alloy	Electrical conductivity (MS/m)			
	Measured values			Mean value
Alloy 1	5.643	5.604	5.591	5.613
Alloy 2	5.626	5.317	5.310	5.418

4. CONCLUSION

Based on the structural analysis of the investigated alloys CuAlAu0.5, which was performed using optical microscopy and SEM-EDS method, the existence of all expected phases was confirmed: solid solutions based on copper, aluminum and gold (Cu, Al, Au) and β phase. Using differential thermal analysis (DTA), the characteristic temperatures of phase transformations of the tested alloys were determined. By measuring the hardness of the alloys, it was determined that the highest values of hardness were measured in alloys whose composition includes the β phase. The results of measuring the microhardness of the alloys show that a high value of microhardness. By measuring the electrical conductivity of alloys, it was determined that the alloys possess high values of electrical conductivity. Based on the obtained results, the further thermodynamic analysis can be validated based on obtained structural, mechanical and electrical characteristics of the alloys.

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