



University of Belgrade
Technical Faculty in Bor,
Mining and Metallurgy
Institute Bor

**54th International
October Conference
on Mining and Metallurgy**

PROCEEDINGS

Editors:

Ljubiša Balanović

Dejan Tanikić



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PREFACE

On behalf of the Organizing Committee, it is a great honor and pleasure to welcome all esteemed participants of the 54th International October Conference on Mining and Metallurgy (IOC 2023), scheduled to take place at the picturesque Bor Lake, Serbia, from October 18th to 21st 2023.

The collaborative efforts of the University of Belgrade, the Technical Faculty in Bor, and the Mining and Metallurgy Institute Bor have meticulously organized this year's IOC. Our focus remains unwavering on showcasing the latest research findings and advancements in geology, mining, metallurgy, materials science, technology, environmental protection, and other engineering disciplines. Our primary objective is to foster a dynamic environment where academics, researchers, and industry professionals can come together to share their knowledge, experiences, and innovative ideas while exploring opportunities for collaborative research endeavors.

Our conference agenda is rich and diverse, encompassing plenary sessions, engaging invited lectures, technical presentations, enlightening oral and poster sessions, informative technical tours, a diverse exhibition, and memorable social gatherings. At the heart of this event lies our strong commitment to sustainable development within the mining and metallurgy sector. We are dedicated to exploring ecologically conscious methodologies, responsible resource extraction practices, and cutting-edge technologies that reduce the industry's environmental impact and enhance the well-being of local communities.

The conference proceedings comprise 129 papers authored by individuals from universities, research institutes, and industries in 22 countries. We are proud to welcome participants from Bosnia and Herzegovina, Bulgaria, Canada, China, Croatia, Germany, Greece, India, Iran, Kazakhstan, Libya, North Macedonia, Montenegro, Morocco, Romania, Russia, Slovakia, South Africa, Spain, Turkey, United States, and, of course, Serbia.

We are excited to host the 8th International Student Conference on Technical Sciences (ISC 2023) as part of IOC 2023. This event offers students from Serbia and the wider region a unique chance to showcase their research and discuss the future of their fields with experts.

We sincerely thank the Ministry of Science, Technological Development, and Innovation of the Republic of Serbia for their generous financial support. In addition, we express our profound gratitude to all our sponsors, exhibitors, and friends of the Conference for their contributions and unwavering support for playing a pivotal role in ensuring the success of IOC 2023.

We would like to express our heartfelt thanks to all authors, committees, reviewers, speakers, and chairpersons for their invaluable contributions in shaping IOC 2023.

We look forward to welcoming you to the 55th International October Conference on Mining and Metallurgy (IOC 2024), which will be held in October 2024.

On behalf of the 54th IOC Organizing Committee,

Prof. dr Ljubiša Balanović

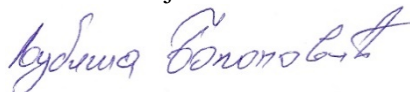


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EXPERIMENTAL INVESTIGATIONS OF CuAlAg ALLOYS WITH 70 at%Cu

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Abstract

Represented results in this paper are obtained from the experimental investigations of the selected as-cast alloys with Cu content of 70 at% in the ternary Cu-Al-Ag system. These investigations included microstructural characterization and experimental determination of hardness, microhardness and electrical conductivity. Microstructure of the investigated alloys has been done by light optical microscopy. In the frame of investigations of some mechanical properties, hardness and microhardness were determined by Vickers standard method. Electrical conductivity was determined too.

Keywords: Copper-rich alloys, Microstructure, Mechanical properties, Electroconductivity

1. INTRODUCTION

Smart materials and shape memory materials, as part of this large group of materials, have been studied very well and in detail for decades [1,2]. A huge number of shape memory alloys of various binary, ternary and multicomponent systems, such as Ag-Cd, Au-Cd, Cu-Sn, Cu-Al-Ag, Cu-Al-Ag-Mg, Cu-Al-Au, Cu-Ag-Au, Cu-Au-Zn, Cu-Zn-Ga, Ni-Al, Ti-Ni-Cu, Ni-Ti-Nb, Ti-Pd-Ni, In-Ti, In-Cd and others, have been obtained and investigated due to the fact that their properties make them convenient for different purposes. Alloys of the Cu-Al-Ag ternary system have also, been studied for a long time but the shape memory effect which is characteristic for these alloys and their good properties are the reason for further research by scientists [3,4,5].

This paper represents the results of the experimental investigations of the CuAlAg alloys chosen along vertical section with constant copper content of 70 at% as an addition to the previous published in ref. [5].

2. EXPERIMENTAL

All alloy samples were cast using induction melting and the purities of the constituent metals, Cu, Al and Ag, were 99,99%. Samples preparation was done under argon atmosphere with total metal losses of the samples less than 1%. All alloys were melted and cooled repeatedly due to improvement of the compositional homogeneity.

A study of the microstructure of the investigated alloys has been done by light optical microscopy using Reichert MeF2 microscope. Hardness and microhardness measurements were carried out using Vickers standard method at a load of 10N and 100g. Electrical conductivity measurements were carried out on "Institute dr. Förster SIGMATEST 2.06" device.

Composition and mass of selected as-cast alloys are shown in Table 1.

Table 1 - Composition and mass of investigated alloys

Sample	X _{Cu}	X _{Al}	X _{Ag}	m _{Cu}	m _{Al}	m _{Ag}
C1	0,7	0,06	0,24	3,0894	0,1124	1,7982
C2	0,7	0,12	0,18	3,3127	0,2411	1,4461
C3	0,7	0,18	0,12	3,5709	0,3899	1,0392
C4	0,7	0,24	0,06	3,8727	0,5638	0,5635

3. RESULTS AND DISCUSSION

All investigated as – cast alloys, C1, C2, C3 and C4, with compositions given in Table 1., are located in the area with 70 at% of copper, based to their chemical compositions and calculated phase diagram [5].

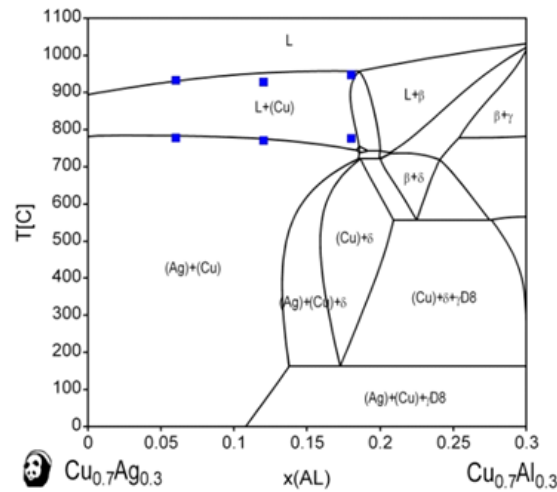


Figure 1 - Calculated vertical sections of the Cu-Al-Ag ternary system with constant copper content of 70at% compared with DTA results [5]

Phase diagram of the calculated vertical section with 70 at% of copper, presented in the Figure 1, shows that the tested alloys mainly belong in the area of primary crystallization - Liquid + (Cu) - copper-based solid solution.

The results of microstructural characterization are presented in the following Figures:

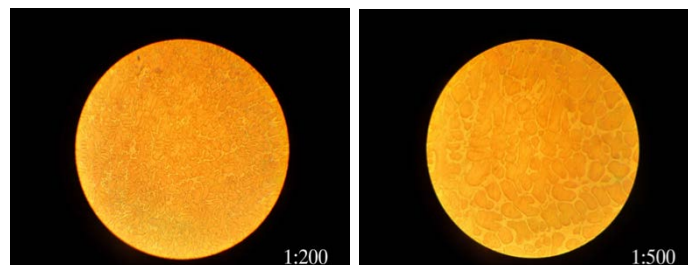


Figure 2 - Sample alloy C1 (Cu₇₀Al₆Ag₂₄)

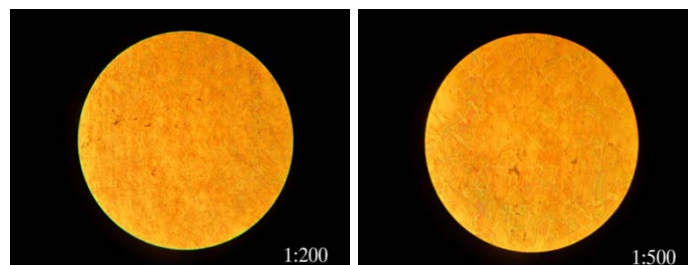


Figure 3 - Sample alloy C2 (Cu₇₀Al₁₂Ag₁₈)

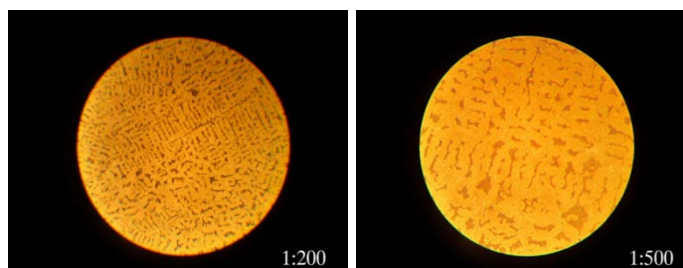


Figure 4 - Sample alloy C3 ($\text{Cu}_{70}\text{Al}_{18}\text{Ag}_{12}$)



Figure 5 - Sample alloy C4 ($\text{Cu}_{70}\text{Al}_{24}\text{Ag}_6$)

The microstructure of the investigated copper-rich samples with 70 % at Cu, which are presented in Figures 2-4, consists of primary crystals of copper based solid solution (Cu) and silver based solid solution (Ag), in the form of precipitates on the edges of copper crystals. Sample C3 in Figure 4 is characterized by a dendritic structure, while in the alloy C4 (Figure 5), exists martensitic structure.

3.1 Hardness and microhardness measurements

The results of the hardness measurements of the alloys samples along the vertical cross-section of 70 at% Cu are presented in Table 2. It is noticeable that with the increase of aluminum content, the hardness values of the tested alloys increase.

Table 2 - Results of the hardness measurements for selected as-cast alloy samples

Sample label	Sample	HV10
C1	$\text{Cu}_{70}\text{Al}_6\text{Ag}_{24}$	95
C2	$\text{Cu}_{70}\text{Al}_{12}\text{Ag}_{18}$	102
C3	$\text{Cu}_{70}\text{Al}_{18}\text{Ag}_{12}$	111
C4	$\text{Cu}_{70}\text{Al}_{24}\text{Ag}_6$	164

Table 3 - Results of the microhardness measurements for selected as-cast alloy samples

Sample label	Sample	HV0.1		
		Measuring point 1	Measuring point 2	Measuring point 3
C1	$\text{Cu}_{70}\text{Al}_6\text{Ag}_{24}$	83	93	78
C2	$\text{Cu}_{70}\text{Al}_{12}\text{Ag}_{18}$	91	128	86
C3	$\text{Cu}_{70}\text{Al}_{18}\text{Ag}_{12}$	166	151	190
C4	$\text{Cu}_{70}\text{Al}_{24}\text{Ag}_6$	309	211	323

As it can be seen in Table 3, microhardness values of the tested alloys increase with the increase in aluminum content

3.2 Electrical conductivity

The results of the electroconductivity measurements are presented in Table 4. Measured values of the electroconductivity of the tested alloys decrease with increase of the aluminum content.

Table 4. Results of the electrical conductivity measurements for selected as-cast alloy samples

Sample label	Sample	Electrical conductivity (MS/m)		
C1	Cu ₇₀ Al ₆ Ag ₂₄	8,4	8,9	8,9
C2	Cu ₇₀ Al ₁₂ Ag ₁₈	5,8	5,8	5,4
C3	Cu ₇₀ Al ₁₈ Ag ₁₂	5,4	5,9	5,8
C4	Cu ₇₀ Al ₂₄ Ag ₆	5,6	5,6	5,7

4. CONCLUSION

This paper represents the obtained results from the experimental investigations of the selected as-cast alloys with Cu content of 70 at% in the ternary Cu-Al-Ag system. The investigations included microstructural characterization and experimental determination of hardness, micro-hardness and electrical conductivity. Microstructure of the investigated alloys has been done by light optical microscopy. Hardness and micro-hardness values of the tested alloys increase with the increase in aluminum content. With increase of the aluminum content, the values of the electro-conductivity of the tested alloys decrease.

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