MINING AND METALLURGY INSTITUTE BOR

and

TEHNICAL FACULTY BOR, UNIVERSITY OF BELGRADE

IOC 2024

International October Conference

55th International October Conference on Mining and Metallurgy

PROCEEDINGS

Editor:
Ana Kostov

15 – 17 October 2024
Hotel "Đerdap" Kladovo, Serbia

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Editor: Ana Kostov

Publisher: Mining and Metallurgy Institute Bor, 2024

Printed in: “GRAFOMED-TRADE” Bor

Text printing preparation: Vesna Simić

Disclaimer: *All full papers and abstracts submitted to the 55th International October Conference on Mining and Metallurgy (55 IOC) are subject to a peer reviewing process, using subject specialists selected because of their expert knowledge in the specific areas. Authors are responsible for the content, translation and accuracy.*

Circulation: 150 copies

CIP – Каталогизација у публикацији
Народна библиотека Србије, Београд

622(082)
669(082)

INTERNATIONAL October Conference on Mining and Metallurgy (55 ; 2024 ; Kladovo)
Proceedings / 55th International October Conference on Mining and Metallurgy – IOC 2024, 15 – 17 October 2024, Kladovo, Serbia ; [organizers] Mining and Metallurgy Institute Bor [and] University of Belgrade, Technical Faculty in Bor ; editor Ana Kostov. - Bor : Mining and Metallurgy Institute, 2024 (Bor : Grafomed-trade). - XXI, 468 str. : ilustr. ; 24 cm

Tiraž 150. - Bibliografija uz svaki rad. - Registar.

ISBN 978-86-7827-053-6
a) Рударство -- Зборници b) Металургија -- Зборници

COBISS.SR-ID 153297161

Kladovo, 15 – 17 October 2024

Conference is financially supported by the
Ministry of Science, Technological Development and
Innovation of the Republic of Serbia,
Contract No. 451-03-4405/2024-03 from 08.07.2024.

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The 55th International October Conference on Mining and Metallurgy
15 - 17 October 2024, Kladovo, Serbia
https://ioc.irmbor.co.rs

DOI: 10.5937/IOC24287K Original Scientific Paper-Material Science

DETERMINING THE ACTIVITY AND COEFFICIENT OF ACTIVITY FOR COMPONENTS IN THE COPPER-BASED SHAPE MEMORY ALLOYS

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Abstract

The shape memory alloys belong to a group of special alloys – smart metallic materials. The copper-based shape memory alloys have a potentially large application in many industrial and technology fields due to the cost-effective alloys regarding the Ti-Ni alloys, promising the shape memory properties and functional properties. This paper presents the results for the activity and coefficient activity values of components in the Cu-Al-Zn copper-based shape memory alloy, obtained by the differential thermal analysis at 1073 K temperature.

***Keywords**: copper-based shape memory alloys, activity, activity coefficient, differential thermal analysis (DTA), Cu-Zn-Al alloys*

1. INTRODUCTION

The shape memory alloys are characterized by the capacity to restore their original pre-deformed shape and size after undergoing a substantial deformation when heated to a certain temperature [1]. This temperature induced the strain recovery and other elasticity variants exhibited by shape memory effect [2]. These alloys recover their pre-deformed morphology when heated above their transition temperatures after being deformed in their lower temperature phase (martensitic phase) [3]. The deformation is due to a reversible re-arrangement of crystal lattice: from martensite twinned to martensite detwinned. The shape memory recovery is obtained by the inverse martensitic transformation (from martensite detwinned to martensite twinned), driven by a temperature modification [4].

According to this ability, the shape memory materials have made them more appropriate for a wide use in various of applications. These includes the biomedical, industrial, thermal, and other domestic applications [5].

Due to these fascinating phenomena, the shape memory alloys have been extensively investigated and of many alloy systems. The Ti-Ni alloys are widely utilized for the industrial and medical products, due to their excellent shape memory effect and mechanical properties. The copper-based shape memory alloys are commercially attractive due to their low cost and high thermal and electrical conductivity [6].

However, even though the NiTi-based shape memory alloys exhibit the great shape memory effect, super elasticity, high biocompatibility, and high corrosion resistance. The manufacturing process is a complex due to its high melting temperature of material, and the material is expensive. The manufacturing cost of the copper-based shape memory alloys is less, and not much difficult process is involved due to its low melting point compared to the NiTi-based shape memory alloys with a wide range of transformation temperature and good shape memory effect.

Even though the copper-based shape memory alloys tend to show the intergranular cracks in the coarse-grained alloys and due to its brittle and high anisotropy property they are considered as an economical alternative to the NiTi-based shape memory alloys, but the efforts are in place to improve the mechanical properties through the grain refining [7].

The copper-based shape memory alloys, such as the Cu-Al and Cu-Zn based shape memory alloys, have been utilized extensively with the ternary elements such as Al, Zn, and Mn, and during the years, Cu-Al-Ni, Cu-Zn-Al, and Cu-Al-Ni have been investigated extensively [8,9].

Due to this reason, the full thermodynamic description and determination the thermodynamic properties such as the activity of components of the copper-based shape memory alloys are important from the scientific and practical point of view.

In this paper, the differential thermal analysis is used for determination the values of the component activity and coefficient of activity in the Cu-Zn-Al copper-based shape memory alloys at 1073 K temperature.

2. EXPERIMENTAL

All experimental investigations are carried out with the high pure metals: copper, zinc and aluminum. The investigated alloys are obtained by melting the charge of the mention metals. The charge melting is carried out in a gas pot furnace. The alloys are cast into moulds of dimensions 5x5x100 mm. After preparation the external surfaces, the laths of dimension 5x5x25 mm are cut and used for the DTA investigations.

Chemical compositions of obtained alloys are shown in Table 1.

Table 1. *Chemical compositions of the Cu-Zn-Al alloys*

No	X_{Cu}	X_{Zn}	X_{Al}
1	0	0.90	0.10
2	0.1	0.81	0.09
3	0.2	0.72	0.08
4	0.3	0.63	0.07
5	0.4	0.54	0.06
6	0.5	0.45	0.05
7	0.6	0.36	0.04
8	0.7	0.27	0.03
9	0.8	0.18	0.02
10	0.9	0.09	0.01
11	1	0	0

The DTA experiments are carried out with heating rates of 10 K/min and at temperature of 1073K, with alumina as referent material and reduced atmosphere of hydrogen.

3. RESULTS AND DISCUSSION

The DTA method is used for determining the activities and coefficient of activities of the copper-based shape memory alloys. According to the obtained DTA curves for each alloy, the temperature of martensitic transformations is obtained, as well as the activities, and coefficient of activities are determined.

The obtained results for activities and coefficient of activities are shown in Tables 2 and 3, respectively.

Table 2. *Activities in the Cu-Zn-Al alloys at 1073K*

No.	a_{Cu}	a_{Zn}	a_{Al}
1	0	0.902	0.128
2	0.085	0.809	0.115
3	0.177	0.714	0.102
4	0.275	0.618	0.088
5	0.376	0.523	0.074
6	0.479	0.429	0.059
7	0.584	0.337	0.046
8	0.689	0.248	0.034
9	0.794	0.161	0.022
10	0.898	0.078	0.010
11	1	0	0

Table 3. *Coefficient of activities in the Cu-Zn-Al alloys at 1073K*

No.	γ_{Cu}	γ_{Zn}	γ_{Al}
1	-	1.002	1.282
2	0.848	0.998	1.283
3	0.885	0.991	1.271
4	0.915	0.980	1.252
5	0.939	0.968	1.226
6	0.958	0.954	1.196
7	0.972	0.937	1.163
8	0.984	0.918	1.127
9	0.992	0.895	1.088
10	0.998	0.868	1.046
11	1	-	-

The obtained results for activities and coefficient of activities of the investigated alloys shows the values in accordance with the Rault's low. The values for activities of all three components of the investigated alloys are less than the unity as well as for the activity coefficient for copper. The coefficient of activities for zinc approach unity only for the alloys no. 1, which is associated with behavior of the binary Zn-Al alloy, while the values for aluminum are greater than unity in the entire concentration range. At the same temperature of 1073K, the activity of copper in the investigated alloys has a tendency to increase, while the activities of zinc and aluminum have tendency to decrease. The activity coefficient for copper also increases with increasing copper content in the alloys, while it decreases with increasing zinc and aluminum contents.

Good miscibility of components in formation the Cu-Zn-Al copper-based shape memory alloys is between copper and zinc, and copper and aluminum, while zinc and aluminum show poor miscibility. Therefore, a smaller percentage of aluminum is present in the ternary alloys, which was added only to reduce the size of grains in the alloy, i.e., obtaining a finer structure suitable for further plastic deformation.

4. CONCLUSION

The DTA method was very effective for determining the activities and coefficient of activities for components in the ternary copper-based shape memory alloys Cu-Zn-Al. The obtained values are in accordance with the Rault's low. The values for activities and coefficient of activities for copper in the copper-based shape memory alloys Cu-Zn-Al are less than unity.

ACKNOWLEDGEMENTS

This work was financially supported by the Ministry of Science, Technological Development and Innovations of the Republic of Serbia, Contract on Realization and Financing the Scientific and Research Work of the Mining and Metallurgy Institute Bor in 2024, Registration No. 451-03-66/2024-03/ 200052.

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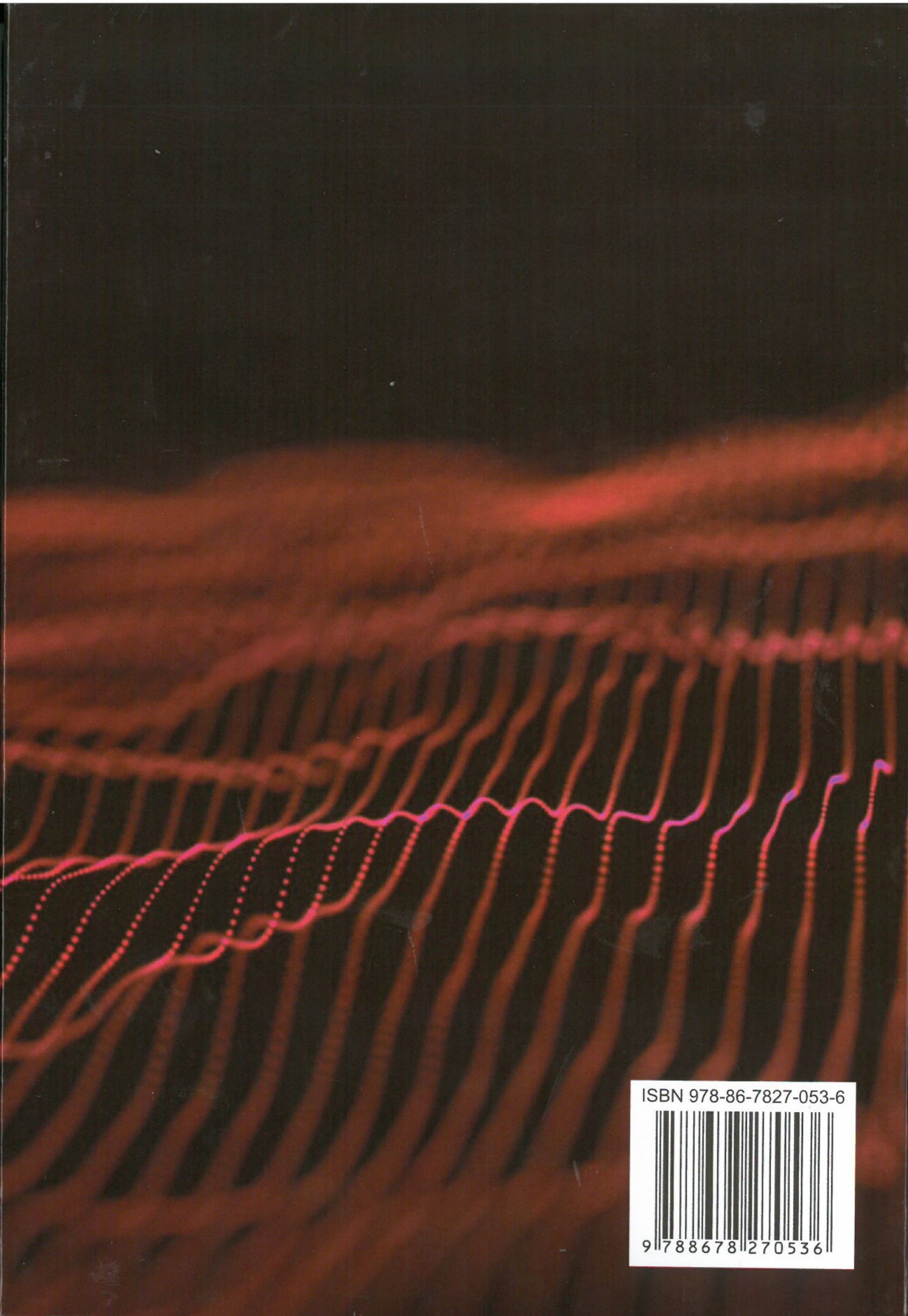

ISBN 978-86-7827-053-6