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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 October18th 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.

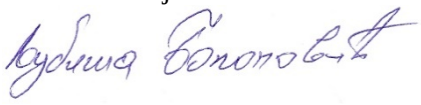
We sincerely thank the Ministry of Science, Technological Development, and Innovation of the Republic of Serbia for their generous financial support. In addition, we express our profound gratitude to all our sponsors, exhibitors, and friends of the Conference for their contributions and unwavering support 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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DETERMINATION OF MELT PROPERTIES IN Cu-Fe ALLOYS

Ana Kostov, Aleksandra Milosavljević, Zdenka Stanojević Šimšić, Ivan Jovanović

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Abstract

The goal of the paper is to find a copper alloys with iron content that would have practical application in electronics as an electronic functional material. The melt properties of the special alloys in system Cu-Fe are given in this paper.

***Keywords**: Cu-Fe alloys, melt, Gibbs free energy*

1. INTRODUCTION

Considering the fact that the world economy has changed in recent years, that there is a recession in world and European industrial countries, and especially in the post-covid period, there was a need for some materials that are used for everyday use to be produced in own country and at that way to avoid their import.

This especially applies to the use of classic metal materials in electronics and electronic industry, where there is the greatest demand.

A lot of attention was given to investigation of special copper alloys with iron in the best laboratory conditions in the world [1-5]. However, these alloys offer remarkable electrical conductivity, thermal conductivity, magnetism, and wear resistance characteristics, making them ideal for applications across a wide range of fields, including 5G/6G communication systems, AI/IoT, medicine/antibacterial uses, and vehicle-mounted equipment. Characteristics can be adjusted by varying the copper and iron content, allowing to offer solutions to suit particular applications.

2. EXPERIMENTAL

Alloys of the Cu-Fe system on the copper side are usually two-component or multi-component copper alloys with iron in the amount of up to 3%. Alloys of copper with iron can also contain some usual amounts of phosphorus and zinc, which are introduced primarily as agents for the deoxidation of copper before the introduction of iron, or they can be additionally alloyed with these components, which significantly improves the mechanical properties without fear that under their influence they can more significantly reduced the electrical conductivity.

Copper alloys with iron belong to the group of alloys with medium electrical conductivity and medium hardness.

The alloys are obtained by classical melting of copper and reduced iron powder in an electric induction furnace and the addition of phosphorus and zinc for the deoxidation of the copper melt.

It is emphasized that the melting of special copper alloys with iron is very important and related to the concept of melting alloys of the Cu-Fe system, according to phase diagram of the Cu-Fe system. The role of phosphorus and zinc in the alloys are also important, given the fact that they are present in amounts of up to 0.15% and 0.20%, respectively.

The chemical composition of the obtained set of the special copper alloys with iron is shown in the Table 1.

Table 1 – Chemical composition of the Cu-Fe alloys

Alloys	Content, %				
	Cu	Fe	P	Zn	Pb
Cu-Fe	balance up to 100%	2.10-2.60	0.03		
Cu-Fe-P	balance up to 100%	2.10-2.60	0.015-0.15	0.20	0.03

3. RESULTS AND DISCUSSION

In order to determine the melt properties of the investigated alloys, the basis of the quasi-chemical theory and the principle of quasi-regular melts, where the averageness of the micro-range is taken into account, are used for calculation of the thermodynamic properties of the investigated alloys of the Cu-Fe system, such as enthalpy of mixing and Gibbs free energy.

The system Cu-Fe belongs to the group of the eutectic alloys in which there is a tendency towards layering or non-mixing in the liquid state, immediately near the liquidus line.

Enthalpy of mixing liquid copper with iron is calculated at two temperatures: 1773K and 1873K. The results are shown in the Table 2.

Table 2 – Enthalpy of mixing in Cu-Fe alloys

Alloys	Temperature, K	Enthalpy, kJ/mol
Cu-Fe	1773	8.37
	1873	8.63
Cu-Fe-P	1773	8.14
	1873	8.19

The change of the Gibbs free energy is calculated at different temperatures: 1473K, 1673K, 1773K and 1873K. The results are shown in Table 3.

Table 3 – Gibbs free energy of Cu-Fe alloys

Alloys	Temperature, K	ΔG kJ/mol
Cu-Fe	1473	-15.84
	1673	-25.38
	1773	-30.16
	1873	-34.94
Cu-Fe-P	1473	-9.52
	1673	-17.67
	1773	-21.75
	1873	-25.82

According to the obtained data, the process of mixing liquid copper with iron is characterized by an endothermic heat effect and the changing of the Gibbs free energy is negative in the investigated temperature range. The thermal effect of mixing the melt is relatively small. The obtained data showed the melt of alloys belong to the group of quasi-regular melts.

Results of surface tension measurement at temperature 1473K, 1673K and 1773K are shown in Figure 1.

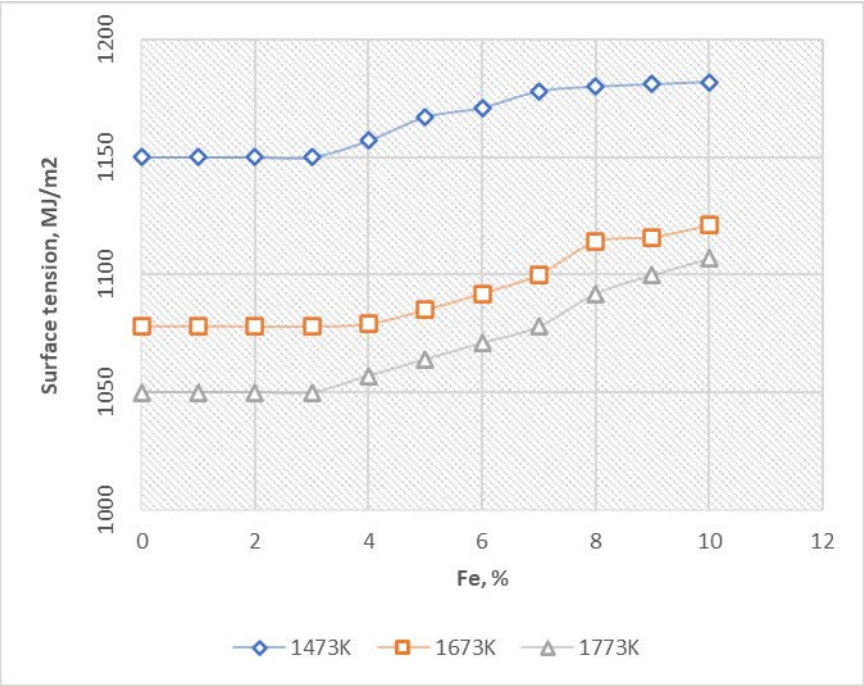

Figure 1 - Surface tension of Cu-Fe alloys at 1473K, 1673K and 1773K

According to the obtained results, isotherms of the surface tension of the Cu-Fe alloys at a content of up to 10 mass% show the surface tension practically does not change at a content of up to 4 mass% of iron, and then begins to increase slowly. In this connection, the best practical application in electronics and for electronic materials is taken alloys with iron content up to 3 mass%.

The specific volume of the alloys is determined for alloys with a higher copper content till 10 mass% of iron and at 1773K. The obtained results are shown in Figure 2.

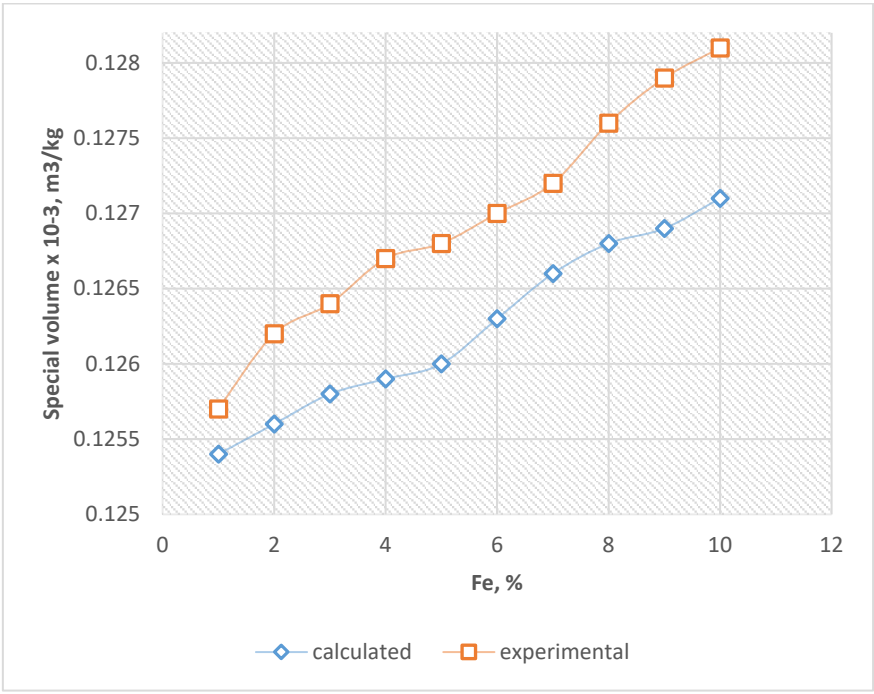

Figure 2 - Specific volume of Cu-Fe alloys at 1773K calculated and experimental values

The obtained results show that in melts rich in copper, even at high overheating for copper alloys up to the order of 1773K-1873K, it is possible to layer the melt by forming iron-enriched groups, that is, emulsion-like melts are obtained.

Based on the Cu-P and Fe-P phase diagrams, it can be seen that copper forms a eutectic with phosphorus. Therefore, the addition of insignificant amounts of phosphorus to the alloy melt in the Cu-Fe system will affect the fact that phosphorus binds more to iron due to its greater affinity compared to the affinity to copper. Due to the stronger mutual bonds of phosphorus with iron in the melt with copper, i.e. the greater affinity between these two elements compared to copper and phosphorus, layering of the alloy will not occur, which will enable obtaining a liquid cast during melting and forming alloys with a satisfactory composition without segregations.

All that mention above should be kept in mind when overcoming the technology of making alloys of this system.

4. CONCLUSION

Obtaining special alloys of copper with iron, which will be used as an electronic material implies obtaining alloys with precisely defined compositions.

The structural properties of alloys in the system Cu-Fe depend first of all on the chemical composition, but also on the solidification conditions of the melt and then on the plastic treatment and thermal treatment.

Therefore, knowing and determining the properties of the melt greatly contributes to obtaining quality alloys with properties that are suitable for wide application in electronics and the electrical industry.

Based on the obtained results, it can be concluded that iron is completely dissolved during melting. The phosphorus content guarantees the complete deoxidation of copper in the process of melting and making alloys.

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