



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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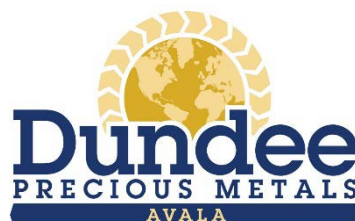


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PREFACE

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

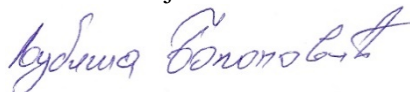


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LATENT HEAT OF SOME ALUMINIUM BASED PHASE CHANGE ALLOYS FOR THERMAL ENERGY STORAGE

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Abstract

Latent heat energy storage (LHES) is one of the most effective methods of thermal energy storage (TES). The knowledge of the thermal properties such as melting point, latent heat of melting, specific heat, thermal diffusivity and thermal conductivity is crucial for the development of the phase change materials (PCMs) for LHES applications. Due to their good properties, aluminium based eutectic alloys have become the most widely studied metal-based PCMs. In the present study, latent heat of melting for Al-12.6% Si, Al-33.3% Cu, and Al-27.8% Cu-5.2% Si (mass %) eutectic alloys were calculated using the CALPHAD (CALculation of PHase Diagram) method and the optimized thermodynamic parameters from the literature. The results of calculations were compared with the experimental results from the literature and good mutual agreement was noticed. The obtained results indicate that the applied calculation approach can be successfully used to predict the latent heat of eutectic alloys.

Keywords: aluminium alloys, phase change material, eutectic, latent heat

1. INTRODUCTION

In terms of the global energy and resource crisis, the development of phase-change energy storage technologies has an increasing role in industrial conditions as well as in daily life [1]. Therefore, in recent years new phase-change materials (PCMs) for thermal energy storage are being investigated, with the ability to accumulate (storage) and release a large amount of thermal energy in the form of latent heat of a reverse phase transformation at a constant temperature. A variety of different materials have been studied so far and commercially implemented in the field of PCMs for heat storage [1,2]. The disadvantage of commercial PCMs such as inorganic salts, is their low thermal conductivity, which significantly limits the heat transfer in the material [1,2]. In order to improve the thermal conductivity, intensive research is being carried out on a variety of metals and eutectic alloys as potential PCMs for heat storage [3-5]. Based on a review of current literature [1-3], it is evident that a large number of eutectic alloys, which have the potential for application in the field of PCMs, are not yet fully investigated and many important physicochemical properties such as eutectic concentration, latent heat of melting, thermal conductivity, specific heat etc. are not determined. The eutectic Al-based alloys have significant potential application in the field of high-temperature PCMs ($T_m > 300$ °C) [3-5]. In the present work, CALPHAD (CALculation of PHase Diagram) method was used for the calculation of phase diagrams of Al-Si, Al-Cu, and Al-Cu-Si systems, identification of eutectic compositions, and determination of latent heat for three eutectic Al based alloys: Al-12.6% Si, Al-33.3% Cu, and Al-27.8% Cu-5.2% Si. The results of calculation were compared with the literature data.

2. THEORETICAL BASIS

The enthalpy of melting (fusion) of a substance, also known as latent heat of melting, is the change in its enthalpy resulting from providing energy, typically heat, to a specific quantity of the substance to change its state from a solid to a liquid, at constant pressure. The knowledge of this thermophysical property of material is very important in determining the possibility of its use in the LHES field. The CALPHAD method [6] is based on the minimization of total Gibbs energy of the system. It employs a variety of thermodynamic models to describe Gibbs energy function

dependencies on composition and temperature of all the phases in the system. The models are tailored to describe the Gibbs energy of a specific phase using thermodynamic parameters. These parameters need to be optimized so that the model can fit the available experimental data for the particular phase. After entering the models together with their fitted parameters into specialized thermodynamic software it is possible to calculate thermodynamic functions (specific heat capacity, enthalpy, Gibbs energy, etc.) and phase equilibria of the system of interest. The accuracy of the calculation largely depends on the quality of thermodynamic assessments included in the database. In the present study, thermodynamic calculations according to the CALPHAD method was done using PANDAT software [7] and COST MP0602 thermodynamic database [8].

3. RESULTS AND DISCUSSION

The literature values of thermophysical properties for pure Al, Cu, and Si are presented in Table 1.

Table 1 - Thermophysical properties of pure Al, Cu, and Si [9]

Metal	Melting point /°C	Latent heat of melting/ Jg ⁻¹	Density/gcm ⁻³	Specific heat capacity/Jg ⁻¹ K ⁻¹	Thermal conductivity /Wm ⁻¹ K ⁻¹
Al	660.4	397	2.6989 at 20 °C	0.9 at 25 °C	247 at 25 °C
Cu	1084.9	205	8.93 at 20 °C	0.386 at 20 °C	398 at 27 °C
Si	1414.0	1807.9	2.329 at 25 °C	0.713 at 27 °C	156 at 27 °C

Phase diagrams of the Al-Si and Al-Cu binary systems, calculated using optimized thermodynamic parameters from [8], are shown in Fig. 1.

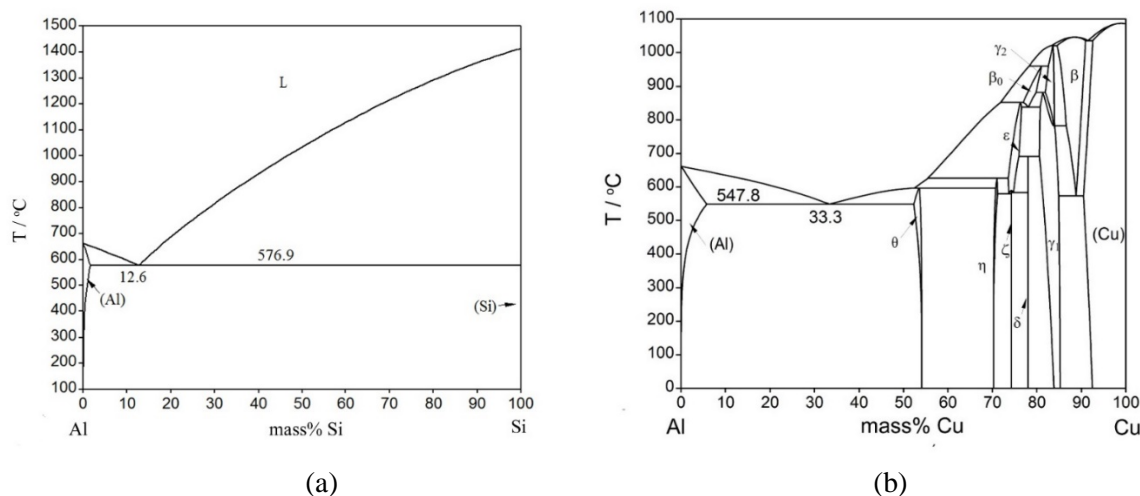


Figure 1 - Phase diagram: (a) Al-Si binary system; (b) Al-Cu binary system

The calculated liquidus projection of the Al-Cu-Si ternary system is presented in Fig. 2. The ternary eutectic composition corresponds to the point marked with the letter E.

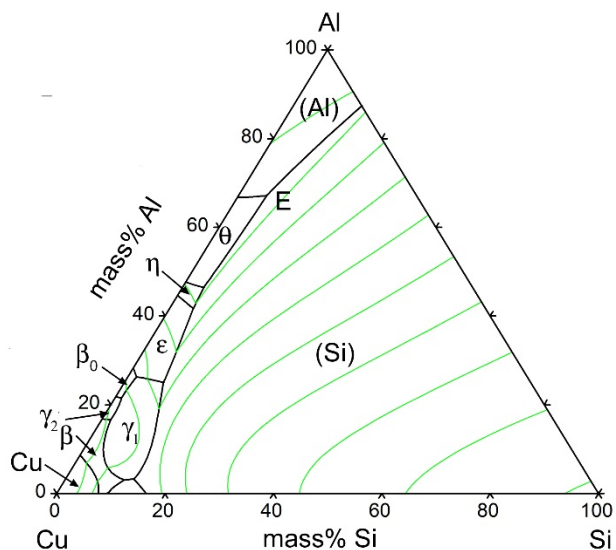


Figure 2 - Calculated liquidus projection of the Al-Cu-Si ternary system

The obtained eutectic reaction, eutectic composition and corresponding eutectic temperature for the Al-Si system are: $L \leftrightarrow (Al) + (Si)$, 12.6% Si, and 576.9 °C. For the Al-Cu system: $L \leftrightarrow (Al) + \theta(Al_2Cu)$, 33.3% Cu, and 547.8 °C. For the ternary Al-Cu-Si system: $L \leftrightarrow (Al) + \theta(Al_2Cu) + (Si)$, 27.8% Cu, 5.2% Si, and 523.4 °C. In the next step, enthalpy variations with temperature for the studied alloys were calculated. Fig. 3 shows the calculated dependence of enthalpy vs. temperature for the investigated Al–12.6% Si alloy with the characteristic jump at the eutectic temperature corresponding to the enthalpy of melting (latent heat of melting- LHM).

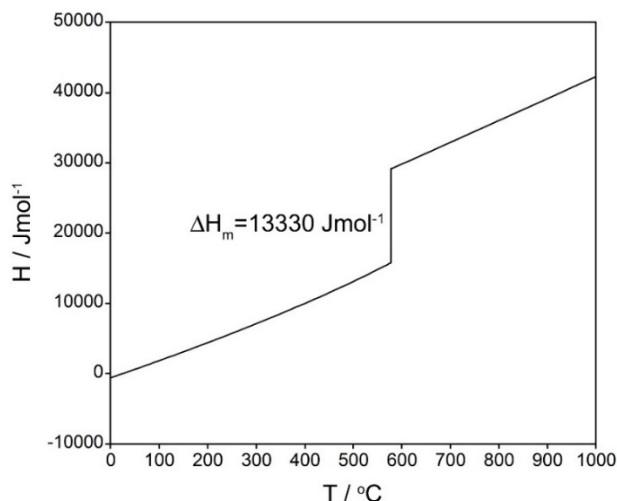


Figure 3 - Temperature dependence of enthalpy for the Al–12.6% Si alloy calculated using optimized thermodynamic parameters from [8]

Table 2 shows the calculated latent heat values for the studied eutectic alloys with the literature data.

Table 2 - Comparison of the calculated and literature values of LHMs for the studied Al based eutectic alloys (Jg⁻¹)

Alloy composition /mass%	Calculation – this work	Literature values	Reference
Al-12.6% Si	491.6	499.2	[3]
Al-33.3% Cu	376.4	331-372	[2]
Al-27.8% Cu-5.2% Si	393.4	361.0	[5]

4. CONCLUSION

Al based eutectic alloys have the potential to be used for thermal energy storage. In the present study, the eutectic temperatures, eutectic compositions, and latent heat of melting of Al-12.6% Si, Al-33.3% Cu, and Al-27.8% Cu-5.2% Si eutectic alloys were calculated using the CALPHAD method and the optimized thermodynamic parameters from literature. The obtained results were compared with the existing literature data. Among the investigated alloys, the Al-12.6% Si alloy has the largest value of latent heat (491.6 Jg⁻¹). Thermodynamic calculation according to the CALPHAD method is a valuable tool in seeking new potential thermal storage materials.

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