



MINING AND METALLURGY INSTITUTE BOR
and
TEHNICAL FACULTY BOR, UNIVERSITY OF BELGRADE



10C 2022
International October
Conference

5rd International October
Conference on Mining
and Metallurgy

PROCEEDINGS

Editors:
Ana Kostov
Milenko Ljubojev

3 – 5 October 2022. Hotel "Albo" Bor, Serbia



MINING AND METALLURGY INSTITUTE BOR

and



TEHNIICAL FACULTY BOR, UNIVERSITY OF BELGRADE



**53rd International October Conference
on Mining and Metallurgy**

PROCEEDINGS

Editors:

**Ana Kostov
Milenko Ljubojev**

3 – 5 October 2022

Hotel “Albo” Bor, Serbia

53rd International October Conference on Mining and Metallurgy

Editors: Ana Kostov, Milenko Ljubojev

Publisher: Mining and Metallurgy Institute Bor

Printed in: “GRAFOMED-TRADE” Bor

**Text printing
preparation:** Vesna Simić

Disclaimer: Authors are responsible for the content, translation and accuracy.

Circulation: 100 copies

CIP – Каталогизација у публикацији
Народна библиотека Србије, Београд

622(082)

669(082)

INTERNATIONAL October Conference on Mining and Metallurgy (53 ; 2022 ; Bor)
Proceedings / 53rd International October Conference on Mining and
Metallurgy - IOC 2022, 3 % 5 October 2022, Bor ; [organizer] Mining and
Metallurgy Bor and Technical Faculty in Bor, University of Belgrade ;
editors Ana Kostov, Milenko Ljubojev. - Bor : Mining and Metallurgy
Institute, 2022 (Bor : Grafomed-trade). - XV, 251 str. : ilustr. ; 25 cm

Tiraž 100. - Bibliografija uz svaki rad. - Registar.

ISBN 978-86-7827-052-9

a) Рударство - Зборници b) Металургија - Зборници

COBISS.SR-ID 74763529

Bor, October 2022

Conference is financially supported by the
Ministry of Education, Science and Technological
Development of the Republic of Serbia



SCIENTIFIC COMMITTEE
53rd International October Conference on Mining and Metallurgy

Dr Mile Bugarin (Serbia) - *President*
Dr Ana Kostov (Serbia) - *Vice President*
Dr Milenko Ljubojev (Serbia) - *Vice President*

Dr Walter Valery, University of Queensland, Australia
Prof. dr Boyan Boyanov, Plovdiv University "Paisii Hilendarski" Plovdiv, Bulgaria
Prof. dr Stoyan Groudev, University of Mining and Geology "Saint Ivan Rilski" Sofia, Bulgaria
Dr Boško Vuković, University of Banja Luka, Faculty of Mining, Banja Luka, Republic of Srpska, B&H
Prof. dr Jelena Penavin Škundrić, University of Banja Luka, Faculty of Technology, Banja Luka, Republic of Srpska, B&H
Prof. dr Kemal Gutić, University of Tuzla, Faculty of Mining, Geology and Civil Engineering, Tuzla, B&H
Prof. dr Mevludin Avdić, University of Tuzla, Faculty of Mining, Geology and Civil Engineering, Tuzla, B&H
Prof. dr Mirsada Oruč, University of Zenica, Faculty of Metallurgy and Technology Zenica, B&H
Dr Sead Softić, International University of Travnik in Travnik, Faculty of Polytechnical Sciences Travnik in Travnik, B&H
Dr Dragan Komljenović, Research Institute, Hydro-Québec, Canada
Prof. dr Vladimir Krstić, Queen's University, Faculty Engineering and Applied Science, Canada
Prof. dr Kaikun Wang, University of Science and Technology Beijing, School of Materials Science and Engineering, China
Prof. dr Yong Du, Central South University Changsha, Hunan, China
Prof. dr Mirko Gojić, University of Zagreb, Faculty of Metallurgy Sisak, Croatia
Prof. dr Natalija Dolić, University of Zagreb, Faculty of Metallurgy Sisak, Croatia
Prof. dr Tamara Holjevac Grgurić, University of Zagreb, Faculty of Metallurgy Sisak, Croatia
Prof. dr Zdenka Zovko Brodarac, University of Zagreb, Faculty of Metallurgy Sisak, Croatia
Prof. dr Carl-Heinz Spitzer, Technical University of Clausthal, Institute for Metallurgy, Germany
Dr Srećko Stopić, RWTH Aachen University, Faculty of Georesources and Materials Engineering, Germany
Prof. dr Dimitris Panias, National Technical University of Athens, School of Mining Engineering and Metallurgy, Greece
Prof. dr Komnitsas Konstantinos, Technical University of Crete, School of Mineral Resources Engineering, Greece
Prof. dr György Kaptay, University of Miskolc, Hungary
Prof. dr Nobuyuki Masuda, Tokyo University of Science, Japan
Prof. dr Essen Suleimenov, Kazakh-British Technical University, Almaty, Kazakhstan
Prof. dr Kemal Delijić, University of Montenegro, Faculty of Metallurgy and Technology Podgorica, Montenegro
Prof. dr Žarko Radović, University of Montenegro, Faculty of Metallurgy and Technology Podgorica, Montenegro
Prof. dr Aleksandar Dimitrov, Ss. Cyril and Methodius University in Skopje, Faculty of Technology and Metallurgy, North Macedonia
Prof. dr Krzysztof Fitzner, AGH University of Science and Technology in Kraków, Poland

Prof. dr Adina Negrea, Politehnica University of Timisoara, Romania
Prof. dr Cornelia Muntean, Politehnica University of Timisoara, Romania
Prof. dr Petru Negrea, Politehnica University of Timisoara, Romania
Prof. dr Sergey Krasikov, Institute of Metallurgy of Ural Branch of the Russian Academy of Sciences, Russia
Dr Slavomír Hredzák, Institute of Geotechnics of the Slovak Academy of Sciences, Kosice, Slovakia
Prof. dr Tomaš Havlik, Technical University of Kosice, Slovakia
Prof. dr Boštjan Markoli, University of Ljubljana, Faculty of Natural Science and Engineering, Slovenia
Prof. dr Jožef Medved, University of Ljubljana, Faculty of Natural Science and Engineering, Slovenia
Prof. dr Batrić Pešić, University of Idaho, College of Engineering, USA
Prof. dr Vladislav Kecojević, West Virginia University, USA
Dr Aleksandra Ivanović, Mining and Metallurgy Institute Bor, Serbia
Dr Aleksandra Milosavljević, Mining and Metallurgy Institute Bor, Serbia
Dr Biserka Trumić, Mining and Metallurgy Institute Bor, Serbia
Dr Branislav Marković, Institute for Technology of Nuclear and other Mineral Raw Materials, Belgrade, Serbia
Prof. dr Branislav Nikolić, Engineering Academy of Serbia, Serbia
Prof. dr Branka Jordović, Academy of Engineering Science of Serbia, Serbia
Prof. dr Grozdanka Bogdanović, University of Belgrade, Technical Faculty Bor, Serbia
Prof. dr Časlav Lačnjevac, Engineering Academy of Serbia, Serbia
Dr Daniel Kržanović, Mining and Metallurgy Institute Bor, Serbia
Dr Daniela Urošević, Mining and Metallurgy Institute Bor, Serbia
Prof. dr Dejan Tanikić, University of Belgrade, Technical Faculty Bor, Serbia
Dr Dragan Milanović, Mining and Metallurgy Institute Bor, Serbia
Prof. dr Dragan Milovanović, University of Belgrade, Faculty of Mining and Geology Belgrade, Serbia
Dr Dragana Božić, Mining and Metallurgy Institute Bor, Serbia
Prof. dr Dragoslav Rakić, University of Belgrade, Faculty of Mining and Geology Belgrade, Serbia
Prof. dr Dejan Ivezić, University of Belgrade, Faculty of Mining and Geology Belgrade, Serbia
Prof. dr Dragan Manasijević, University of Belgrade, Technical Faculty Bor, Serbia
Prof. dr Dragoslav Gusković, University of Belgrade, Technical Faculty Bor, Serbia
Prof. dr Duško Minić, University of Priština, Faculty of Technical Sciences Kosovska Mitrovica, Serbia
Dr Emina Požega, Mining and Metallurgy Institute Bor, Serbia
Prof. dr Ivan Mihajlović, University of Belgrade, Technical Faculty Bor, Serbia
Dr Ivana Jovanović, Mining and Metallurgy Institute Bor, Serbia
Dr Jasmina Stevanović, University of Belgrade, Institute of Chemistry, Technology and Metallurgy Belgrade, Serbia
Dr Jasna Stajić Trošić, University of Belgrade, Institute of Chemistry, Technology and Metallurgy Belgrade, Serbia
Prof. dr Milan Antonijević, University of Belgrade, Technical Faculty Bor, Serbia
Prof. dr Milan Barać, Engineering Academy of Serbia, Serbia

Prof. dr Milan Trumić, University of Belgrade, Technical Faculty Bor, Serbia
Prof. dr Milovan Vuković, University of Belgrade, Technical Faculty Bor, Serbia
Prof. dr Miloš Rajković, Engineering Academy of Serbia, Serbia
Prof. dr Miomir Pavlović, Engineering Academy of Serbia, Serbia
Dr Mirjana Stojanović, Engineering Academy of Serbia, Serbia
Dr Miroslav Sokić, Institute for Technology of Nuclear and other Mineral Raw Materials, Belgrade, Serbia
Prof. dr Nada Štrbac, University of Belgrade, Technical Faculty Bor, Serbia
Dr Nadežda Talijan, Academy of Engineering Science of Serbia, Serbia
Prof. dr Nedeljko Magdalinović, Engineering Academy of Serbia, Serbia
Prof. dr Nenad Vušović, University of Belgrade, Technical Faculty Bor, Serbia
Prof. dr Rade Jelenković, University of Belgrade, Faculty of Mining and Geology Belgrade, Serbia
Dr Radmila Marković, Mining and Metallurgy Institute Bor, Serbia
Prof. dr Radoje Pantović, University of Belgrade, Technical Faculty Bor, Serbia
Dr Renata Kovačević, Mining and Metallurgy Institute Bor, Serbia
Dr Sanja Petrović, Mining and Metallurgy Institute Bor, Serbia
Dr Saša Miletić, Engineering Academy of Serbia, Serbia
Dr Silvana Dimitrijević, Mining and Metallurgy Institute Bor, Serbia
Dr Slavica Miletić, Mining and Metallurgy Institute Bor, Serbia
Prof. dr Snežana Milić, University of Belgrade, Technical Faculty Bor, Serbia
Prof. dr Snežana Šrbula, University of Belgrade, Technical Faculty Bor, Serbia
Dr Stefan Đorđievski, Mining and Metallurgy Institute Bor, Serbia
Prof. dr Svetlana Ivanov, University of Belgrade, Technical Faculty Bor, Serbia
Prof. dr Tatjana Volkov-Husović, University of Belgrade, Faculty of Technology and Metallurgy, Belgrade, Serbia
Dr Vaso Manojlović, University of Belgrade, Faculty of Technology and Metallurgy, Belgrade, Serbia
Dr Vesna Conić, Mining and Metallurgy Institute Bor, Serbia
Dr Vesna Krstić, Mining and Metallurgy Institute Bor, Serbia
Dr Viša Tasić, Mining and Metallurgy Institute Bor, Serbia
Dr Vladan Ćosović, University of Belgrade, Institute of Chemistry, Technology and Metallurgy Belgrade, Serbia
Dr Vojislav Bogdanović, Engineering Academy of Serbia, Serbia
Prof. dr Vukoman Jokanović, Engineering Academy of Serbia, Serbia
Dr Zdenka Stanojević Šimšić, Mining and Metallurgy Institute Bor, Serbia
Dr Zoran Stevanović, Mining and Metallurgy Institute Bor, Serbia
Prof. dr Zvonko Gulišija, Engineering Academy of Serbia, Serbia
Prof. dr Željko Kamberović, University of Belgrade, Faculty of Technology and Metallurgy, Belgrade, Serbia

ORGANIZING COMMITTEE
53rd International October Conference on Mining and Metallurgy

Dr Ana Kostov, Mining and Metallurgy Institute Bor – *President*

Dr Milenko Ljubojev, Mining and Metallurgy Institute Bor – *Vice President*

Dr Dragan Manasijević, UB, Technical Faculty Bor, Serbia – *Vice President*

Suzana Cvetković, Mining and Metallurgy Institute Bor, secretary

Dr Aleksandra Milosavljević, Mining and Metallurgy Institute Bor, member

Lidija Đurđevac Ignjatović, Mining and Metallurgy Institute Bor, member

Nevenka Vukašinović, Mining and Metallurgy Institute Bor, member

Vesna Simić, Mining and Metallurgy Institute Bor, member

Marijana Pavlov Kagadejev, Mining and Metallurgy Institute Bor, member

Saša Stojanov, Mining and Metallurgy Institute Bor, member

Slavoljub Obradović, Mining and Metallurgy Institute Bor, member



TABLE OF CONTENTS

PLENARY LECTURES

Nikhil Dhawan

| | |
|--|---|
| RECYCLING OF ELECTRONIC WASTE FOR RECOVERY OF THE METALLIC VALUES | 3 |
|--|---|

Aleksandra Ivanovic

| | |
|---|---|
| APPLICATION OF THE SIMPLEX METHODS FOR TESTING THE INFLUENCE OF COLD DEFORMATION LEVELS, ANNEALING TEMPERATURE AND CHEMICAL CONTENT ON THE MECHANICAL CHARACTERISTICS OF SOME ALLOYS OF THE Pd-Au SYSTEM | 5 |
|---|---|

Saša Stojadinović, Dejan Petrović

| | |
|---|---|
| ECONOMIC JUSTIFICATION FOR EXPLOITATION THE BORON MINERALS IN BALJEVAC | 9 |
|---|---|

Mirko Stijepović

| | |
|---|----|
| APPLICATION OF OPTIMIZATION IN THE INDUSTRIAL PROCESSES | 13 |
|---|----|

GEOLOGY, MINING AND MINERAL PROCESSING

Tamara Maričić, Marijana Pantić, Marina Nenковиć-Riznić

| | |
|--|----|
| THE CRITERIA AND INDICATORS FOR DEFINING THE SOCIAL ASPECTS IN SPATIAL PLANNING OF MINING REGIONS | 19 |
|--|----|

*Radmilo Rajković, Daniel Kržanović, Miomir Mikić,
Milenko Jovanović, Emina Požega*

| | |
|---|----|
| FORMATION OF A REACTIVE MATERIAL DUMP FROM THE "ČUKARU PEKI" MINE NEAR BOR | 25 |
|---|----|

*Daniel Kržanović, Radmilo Rajković, Milenko Jovanović,
Miomir Mikić, Sandra Milutinović*

| | |
|--|----|
| MEDIUM-TERM PLANNING OF COPPER ORE EXPLOITATION AT THE OPEN PIT VELIKI KRIVELJ NEAR BOR, SERBIA | 29 |
|--|----|

*Sandra Milutinović, Milena Kostović, Ivana Jovanović,
Miomir Mikić, Daniel Kržanović*

| | |
|---|----|
| DETERMINATION THE ADVANTAGE OF SOLUTION IN EASTERN SERBIA USING THE FTOPSIS METHOD AND COMPARISON WITH THE TOPSIS METHOD | 33 |
|---|----|

Snežana Ignjatović, Milanka Negovanović

| | |
|---|----|
| DEFINING THE LOCATION AND DIP OF MAGNETIC ANOMALY SOURCES APPLYING THE MATHEMATICAL TRANSFORMATION | 39 |
|---|----|

Ivan Jovanović, Mladen Supić, Katarina Milivojević, Dušan Tašić

| | |
|---|----|
| VENTILATION AND DISCHARGE SYSTEMS IN THE MINES WITH THE UNDERGROUND EXPLOITATION OF NON-FERROUS METALS | 43 |
|---|----|



53rd International October Conference on Mining and Metallurgy

3 - 5 October 2022, Bor, Serbia

<https://ioc.irmbor.co.rs>

| | |
|--|----|
| <i>Srdana Magdalinović, Silvana Dimitrijević, Aleksandra Ivanović, Stevan Dimitrijević, Stefan Đorđević</i> APPLICATION OF MINERAL PROCESSING METHODS IN RECYCLING THE WASTE PRINTED CIRCUIT BOARDS | 47 |
| <i>Lidija Đurđević Ignjatović, Vesna Krstić, Vanja Đurđević, Dragan Ignjatović</i> THE USE OF CEMENT PASTE IN THE MINING INDUSTRY AND ECOLOGY | 51 |
| <i>Dragan Ignjatović, Dušan Tašić, Vanja Đurđević, Lidija Đurđević Ignjatović</i> WICKHAM AND BIENAWSKI ROCK CLASSIFICATION IN MINING | 55 |
| <i>Katarina Milivojević, Mladen Supić, Ivan Jovanović, Dušan Tašić</i> METHODS OF DEFINING THE SWELING VOLTAGE AT EXPANSIVE SOILS | 59 |
| <i>Sanja Petrović, Grozdanka Bogdanović</i> THE EFFECT OF ALCOHOL ON LEACHING BY HYDROGEN PEROXIDE IN SULFURIC ACID SOLUTION | 63 |
| <i>Vladan Kašić, Slobodan Radosavljević, Vladimir Simić, Ana Radosavljević-Mihajlović, Jovica Stojanović, Slavica Mihajlović, Melina Vukadinović</i> PRELIMINARY GENETIC MODEL OF ZEOLITIC TUFF DEPOSITS IN THE TERTIARY BASINS OF SERBIA | 67 |
| <i>Sladana Krstić, Sanja Petrović, Ivana Jovanović, Slavica Miletić, Emina Požega, Daniela Urošević, Lidija Kalinović</i> APPRAISAL OF USABILITY THE DISINTEGRATED GRAVELLY SANDSTONE (TO THE GRADE OF NATURAL MIXTURE OF SAND AND GRAVEL) | 71 |
| <i>Ivana Jovanović, Sandra Milutinović, Mile Bugarin, Igor Svrkota, Dragan Milanović</i> COMPARISON OF THE SAG MILL POWER CALCULATION BY DIFFERENT METHODS | 75 |
| <i>Ivana Jovanović, Vesna Conić, Ana Kostov, Daniel Kržanović, Sandra Milutinović</i> EXAMPLE OF THE ANN CONTROL SYSTEM FOR THE FLOTATION PLANT | 79 |
| <i>Ivana Jovanović, Jasmina Nešković, Sonja Milićević, Milenko Ljubojev, Predrag Ivanović</i> DEPENDENCE OF THE OVERFLOW PARTICLE SIZE ON THE INLET SLURRY PRESSURE OF THE INDUSTRIAL HYDROCYCLONE | 83 |
| <i>Jovica Sokolović, Zoran Štirbanović, Ivana Ilić, Sandra Vasković</i> APPLICATION OF A COPPER SLAG AS A CONSTRUCTION MATERIAL | 87 |

METALLURGY, MATERIAL SCIENCE, TECHNOLOGY AND CHEMISTRY

| | |
|---|-----|
| <i>Zoran Karastojković, Ana Kostov, Radiša Perić</i> REASONS FOR BRAZING WITH COPPER FILLER METAL ALLOYED WITH THE COPPER (I) AND IRON (III) OXIDES | 93 |
| <i>Srdan Matijašević, Veljko Savić, Vladimir Topalović, Jovica Stojanović, Jelena Nikolić, Snežana Zildžović, Snežana Grujić</i> COMPLEX CRYSTALLIZATION OF THE POTASSIUM-NIOBIUM-GERMANATE SYSTEM ... | 97 |
| <i>Veljko Savić, Vladimir Topalović, Jelena Nikolić, Srdan Matijašević, Snežana Zildžović, Snežana Grujić</i> SINTER-CRYSTALLIZATION OF COAL FLY ASH BASED GLASS | 101 |



53rd International October Conference on Mining and Metallurgy

3 - 5 October 2022, Bor, Serbia

<https://ioc.irmbor.co.rs>

| | |
|--|-----|
| <i>Nebojša Tadić, Žarko Radović</i> THE EFFECTS OF INITIAL PROFILE ON THE SHAPE OF COLD ROLLED STRIPS | 105 |
| <i>Žarko Radović, Nebojša Tadić, Sanja Šćepanović</i> THE EFFECT OF CHEMICAL COMPOSITION ON THE EAF DUST RECYCLING | 111 |
| <i>Ana Petrović, Radmila Marković, Emina Požega</i> STRUCTURE AND PROPERTIES OF CARBON NANOTUBES: A REVIEW | 115 |
| <i>Mirjana Stojanović, Milan Adamović, Jasmina Kustura, Enita Kurtanović, Muhamed Harbinja</i> MULTIFUNCTIONAL FERTILIZER BASED ON PYROPHYLLITE IN ACCORDANCE WITH THE REGULATION EU 2019/1009 | 119 |
| <i>Emina Požega, Saša Marjanović, Milijana Mitrović, Milenko Jovanović, Ana Petrović, Radmilo Rajković, Slavica Miletić</i> ELECTRONIC TRANSPORT PROPERTIES OF THE Bi _{0.5} As _{1.5} Te _{2.98} Se _{0.02} SINGLE CRYSTAL: PART I | 123 |
| <i>Emina Požega, Anja Radičević, Danijela Simonović, Ana Petrović, Zdenka Stanojević Šimšić, Radmilo Rajković, Miomir Mikić</i> ELECTRONIC TRANSPORT PROPERTIES OF THE Bi _{0.5} As _{1.5} Te _{2.98} Se _{0.02} SINGLE CRYSTAL: PART II | 127 |
| <i>Franjo Kozina, Zdenka Zovko Brodarac, Luka Zeljko, Barbara Tubić Bulat, Primož Mrvar, Almir Mahmutović, Snježana Zeljko</i> TECHNOLOGICAL DEVELOPMENT OF THE CASTING PROCESS FOR THE THIN-WALLED GRAY CAST IRON | 131 |
| <i>Zdenka Stanojević Šimšić, Ana Kostov, Aleksandra Milosavljević, Emina Požega</i> CHARACTERISATION OF THE CuAlAg ALLOYS WITH 90 at. % Cu | 135 |
| <i>Vladimir Topalović, Srdan Matijašević, Jelena Nikolić, Veljko Savić, Marija Došić, Snežana Grujić</i> THE EFFECT OF La ₂ O ₃ ADDITION ON THE CRYSTALLIZATION CHARACTERISTICS OF POLYPHOSPHATE GLASSES | 139 |
| <i>Anja Antanasković, Dragan Radulović, Mladen Bugarčić, Tatjana Šoštarić, Vladimir Adamović, Zorica Lopičić, Milan Milivojević</i> IMMOBILIZED BENTONITE IN THE ALGINATE MATRIX – EFFICIENT SORBENT OF BRILLIANT GREEN | 143 |
| <i>Marko Pavlović, Marina Dojčinović, Aleksandar Sedmak, Igor Martić, Filip Vučetić, Zagorka Acimović</i> SYNTHESIS AND CHARACTERISATION OF THE MULLITE-BASED PROTECTIVE COATINGS | 147 |
| <i>Ana Kostov, Zdenka Stanojević Šimšić, Aleksandra Milosavljević, Ivan Jovanović</i> MICROSTRUCTURAL ANALYSIS OF CuAlAu ALLOYS | 151 |
| <i>Milijana Mitrović, Saša Marjanović, Biserka Trumić, Jasmina Petrović, Emina Požega, Miloš Janošević</i> INFLUENCE OF THERMO-MECHANICAL PROCESSING PARAMETERS ON THE TENSILE STRENGTH OF COPPER WIRE PRODUCED BY THE "UP CAST" PROCESS | 155 |

| | |
|--|-----|
| <i>Saša Marjanović, Milijana Mitrović, Emina Požega, Biserka Trumić, Miloš Janošević</i> HARDNESS OF BIMETALLIC STRIP Cu – Č.4571 AFTER THE COLD ROLLING AND ANNEALING | 161 |
| <i>Milijana Mitrović, Saša Marjanović, Jasmina Petrović, Emina Požega, Miloš Janošević</i> INFLUENCE OF CHEMICAL COMPOSITION ON THE QUALITY OF CASTINGS OBTAINED BY THE EASY MELTING MODELS | 165 |
| <i>Silvana B. Dimitrijević, Suzana Veličković, Filip Veljković, Sladana Alagić, Stevan P. Dimitrijević, Aleksandra T. Ivanović, Saša Ivanović</i> CHARACTERIZATION OF THE GOLD MERCAPTOTRIAZOLE COMPLEX USING THE TANDEM QUADRUPOLE MASS SPECTROMETRY (TQD) | 169 |
| <i>Vesna Marjanović, Radmila Marković, Aleksandra Ivanović</i> SCANNING ELECTRON MICROSCOPY (SEM) METHOD IN A COMBINATION WITH THE ENERGY-DISPERSIVE SPECTROSCOPY (EDS) FOR ANALYSIS THE SURFACE OF HYDROUS IRON OXIDE-IMPREGNATED HYBRID POLYMER USED FOR SELENIUM ADSORPTION | 173 |
| <i>Vesna Marjanović, Radmila Marković, Silvana Dimitrijević, Zoran Stevanović</i> ANALYSIS THE SURFACE OF MODIFIED LIGNIN BASED MICROSPHERES USED FOR SELENIUM ADSORPTION BY THE SEM-EDS ANALYTICAL METHOD | 177 |
| <i>Ionelia Voiculescu, Victor Geanta, Radu Stefanioiu, Diana Chioibas, Andrei Popescu, Nicu Scarisoreanu, Emilia Binchiciu</i> CHARACTERIZATION OF ALUMINA COMPOSITE THIN COATINGS MADE BY THE DIRECT LASER DEPOSITION ON A HIGH ENTROPY ALLOY | 181 |
| <i>Rustam Sharipov, Essen Suleimenov, Bolysbek Utebayev, Galymzhan Maldybayev, Maxat Myrzakhanov</i> APPLICATION OF COMBINED ELECTROCHEMICAL REACTIONS IN METALLURGICAL TECHNOLOGIES | 187 |
| <i>Rustam Sharipov, Maxat Myrzakhanov, Essen Suleimenov, Bolysbek Utebayev</i> CORROSION: PROBLEMS AND CHALLENGES | 191 |
| <i>Vesna Conić, Suzana Dragulović, Dragana Božić, Dragan Milanović, Ivana Jovanović, Srđan Stanković, Jelena Avdalović</i> CORRELATION OF Fe ²⁺ WITH Cu ²⁺ AND Zn ²⁺ IN THE BIOLEACHING PROCESS | 195 |
| <i>Vesna Conić, Suzana Dragulović, Dragana Božić, Dragan Milanović, Ivana Jovanović, Srđan Stanković, Jelena Avdalović</i> COMBINATION OF CHEMICAL AND BIOLEACHING PROCESS FOR Cu AND Zn RECOVERY FROM THE SEDEX TYPE ORE | 199 |

ENVIRONMENTAL PROTECTION

| | |
|--|-----|
| <i>Vesna Marjanović, Aleksandra Ivanović, Nevena Marjanović</i> SIGNIFICANCE OF THE SWOT ANALYSIS FOR MONITORING THE IMPROVEMENTS OF APPLICATIONS THE ISO 14001: 2015 STANDARD | 205 |
|--|-----|



53rd International October Conference on Mining and Metallurgy

3 - 5 October 2022, Bor, Serbia

<https://ioc.irmbor.co.rs>

| | |
|--|-----|
| <i>Milenko Jovanović, Daniel Kržanović, Radmilo Rajković, Miomir Mikić, Emina Požega</i> ADVANTAGES AND PURPOSE OF BIOCOMPOSITE GEOGRIDS | 209 |
| <i>Milenko Jovanović, Daniel Kržanović, Radmilo Rajković, Miomir Mikić, Emina Požega</i> APPLICATION OF GEOGRIDS IN RECULTIVATION MEASURES OF DEGRADED LAND | 213 |
| <i>Miomir Mikić, Emina Požega, Radmilo Rajković, Milenko Jovanović, Daniel Kržanović</i> RECULTIVATION OF DEGRADED AREAS FORMED BY DEPOSITION OF TAILINGS AT THE FLOTATION TAILING DUMP "STUBIČKI POTOK", LEPOSAVIĆ | 217 |
| <i>Viša Tasić, Tatjana Apostolovski-Trujić, Ivan Lazović, Nikola Mirkov, Zvonko Damnjanović</i> AUTOMATIC METEOROLOGICAL STATION (AMS/2022) BASED ON THE LOW-COST SENSORS (part 1) | 221 |
| <i>Viša Tasić, Tatjana Apostolovski-Trujić, Ivan Lazović, Nikola Mirkov, Zvonko Damnjanović</i> AUTOMATIC METEOROLOGICAL STATION (AMS/2022) BASED ON THE LOW-COST SENSORS (part 2) | 225 |
| RELATED FIELDS: MECHANICAL ENGINEERING, CIVIL ENGINEERING, ARCHITECTURE, ELECTRONICS, INFORMATICS, MANAGEMENT, ETC. | |
| <hr/> | |
| <i>Nenad Marković, Slobodan Bjelić, Filip Marković</i> SIMULATION MODEL OF DYNAMIC STATES IN AN ASYNCHRONOUS MACHINE WITH A SHORT-CIRCUITED ROTOR | 231 |
| <i>Slavica Miletić, Marko Trišić, Ana Milijić, Emina Požega, Sladana Krstić</i> AHP ANALYSIS OF THE COMPETENT LABORATORY ACCREDITATION STAFF | 237 |
| <i>Tanja Stanković, Nikola Stanić, Dejan Bugarin, Aleksandar Milijanović</i> ECONOMIC ANALYSIS OF INVESTMENTS IN CAPACITY INCREASE TO 1,000,000 TONS OF LIMESTONE AT THE KAONA SURFACE MINE NEAR KUČEVO | 241 |
| INDEX OF AUTHORS | 247 |

MICROSTRUCTURAL ANALYSIS OF CuAlAu ALLOYS

**Ana Kostov¹, Zdenka Stanojević Šimšić¹,
Aleksandra Milosavljević¹, Ivan Jovanović¹**

¹Mining and Metallurgy Institute Bor, Zeleni bulevar 35, 19210 Bor, Serbia,
ana.kostov@irmbor.co.rs

Abstract

Microstructural analysis of the CuAlAu alloys has been carried out experimentally using the light optical microscopy and scanning electron microscopy with the energy dispersive spectroscopy. Based on the obtained structural analysis, the existence of all expected phases was confirmed: solid solutions based on copper, aluminum and gold (Cu, Al, Au), β and γ phases, as well as the intermetallic compounds $AuAl_2$, Al_2Cu , and $AlCu$.

Keywords: optical microscopy, scanning electron microscopy with energy dispersive spectroscopy, CuAlAu alloys

1 INTRODUCTION

The CuAlAu alloys have not been sufficiently investigated despite the fact that the constituent metals copper, aluminum and gold have been known since the ancient times and the constitutive binary alloys CuAu, CuAl and AlAu have been studied in detail. Greater interest for these alloys emerged in the early 2000s with the appearance of papers suggesting the existence of three-component and four-component, 18-carat gold alloys characterized by a shape memory effect. [1,2]

The latest research has been focused on the study of structural changes within the α and β phases, as well as the martensitic transformation, and phenomena that occurred to these transformations in the alloys. [3,4]

These alloys are suitable for making jewelry because, thanks to their crystalline structure and characteristic phase transformations, after adequate heat treatment, their surface becomes “glittery”, allowing such light refraction to achieve a bright, sparkling reflection.

The main goal of the paper is the microstructural analysis of the CuAlAu alloys by the experimentally used the light optical microscopy (LOM) and scanning electron microscopy with the energy dispersive spectroscopy (SEM-EDS).

2 EXPERIMENTAL

All samples were prepared by the inductive melting of pure metals (copper, aluminum and gold) in electric inductive furnace with a protective argon atmosphere. The used pure metals had purity greater than 99.99 wt.%. The total weight loss of prepared samples was less than 1% by weight.

The LOM method was carried out using a Reichert MeF2 microscope with a maximum magnification of up to 500 times for the microstructural analysis of samples. Sample preparation for optical microscopy was performed by grinding (abrasive papers marked 3 to 0000 ASTM), mechanical polishing with an aqueous suspension of alumina

with granulation of 0.05 μm and immersion in the auto-polymerizing acrylate under the trade name SIMGAL.

The SEM-EDS analysis was performed on a scanning electron microscope SEM Tescan VEGA TS 5136MM, resolution 3nm at 20kV and maximum magnification up to 100,000 times, with an energy dispersive spectroscopy brand Bruker.

3 RESULTS AND DISCUSSION

Cross sections with the molar ratios Au:Cu = 1:1 from the angle of aluminum was selected for the experimental investigations in the CuAlAu alloys. The as-cast alloys were used in all tests.

The microstructure of samples, taken with the light optical microscope, is presented in Figures 1-4, respectively.

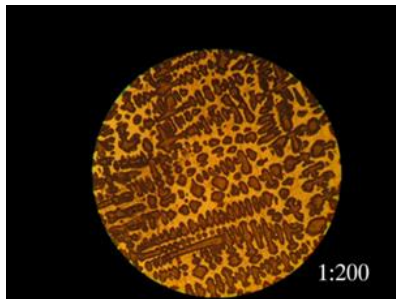


Figure 1 LOM of $\text{Cu}_{40}\text{Al}_{20}\text{Au}_{40}$ alloy

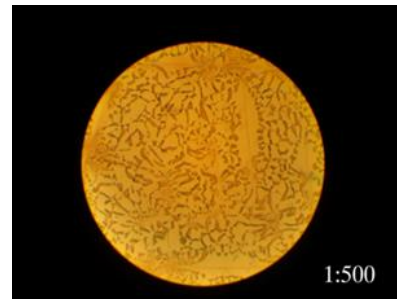


Figure 2 LOM of $\text{Cu}_{30}\text{Al}_{40}\text{Au}_{30}$ alloy

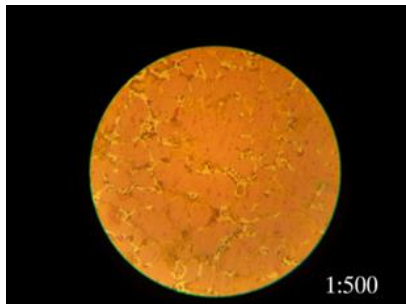


Figure 3 LOM of $\text{Cu}_{20}\text{Al}_{60}\text{Au}_{20}$ alloy

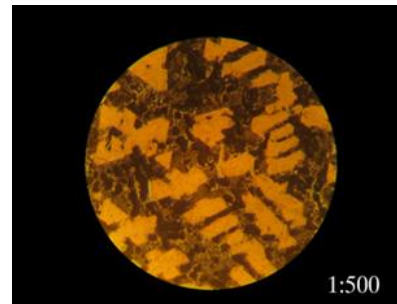


Figure 4 LOM of $\text{Cu}_{10}\text{Al}_{80}\text{Au}_{10}$ alloy

The microstructure of $\text{Cu}_{40}\text{Al}_{20}\text{Au}_{40}$ alloy consists of the small, oval and elongated crystals of a solid solution of copper, aluminum and gold (Cu, Al, Au), and the β phase as a base. The $\text{Cu}_{30}\text{Al}_{40}\text{Au}_{30}$ alloy is characterized by a fine-grained γ phase structure. The microstructure of $\text{Cu}_{20}\text{Al}_{60}\text{Au}_{20}$ alloy consists of crystals of the intermetallic compound AuAl_2 at the edges of which is the intermetallic compound AlCu , and ϵ phase. The microstructure of the $\text{Cu}_{10}\text{Al}_{80}\text{Au}_{10}$ alloy consists of the primary crystals of

the intermetallic compound AuAl_2 , crystals of the intermetallic compound Al_2Cu of lamellar shape, and crystals of a solid solution of aluminum (Al).

The spectra of the $\text{Cu}_{10}\text{Al}_{80}\text{Au}_{10}$ alloy and its characteristic phases are shown in Figures 5.

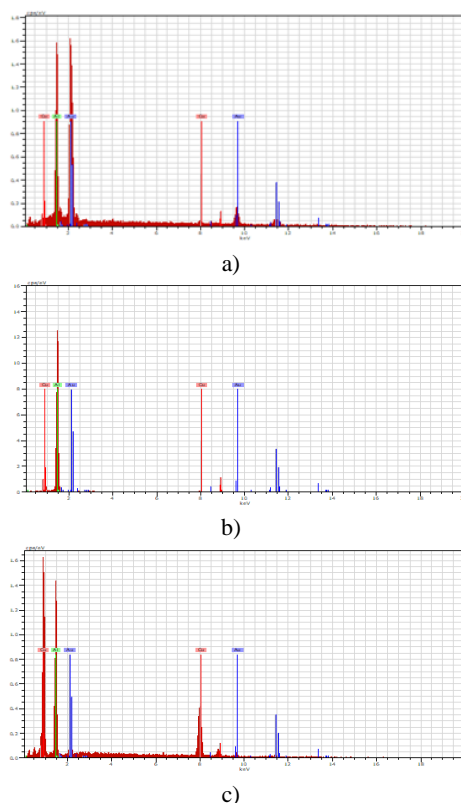


Figure 5 EDS analysis of $\text{Cu}_{10}\text{Al}_{80}\text{Au}_{10}$ alloy: a) AuAl_2 ($\text{Cu}_{3.5}\text{Al}_{62}\text{Au}_{34.5}$); b) (Al) ($\text{Cu}_3\text{Al}_{96}\text{Au}_1$); c) Al_2Cu ($\text{Cu}_{32}\text{Al}_{66}\text{Au}_2$)

Based on the performed structural analysis, using the SEM-EDS method, the presence or existence of all expected phases in the CuAlAu alloys was confirmed.

The phases identified in the CuAlAu alloys from the cross section $\text{Cu}:\text{Au} = 1:1$, are β , ϵ and γ phases, solid solution based on aluminum (Al), solid solution based on gold, aluminum and copper, (Au, Al, Cu), as well as the intermetallic compounds AuAl_2 , Al_2Cu and AlCu .

4 CONCLUSION

The results of experimental microstructural analysis of CuAlAu alloys were presented in this paper. Microstructural analysis of the investigated CuAlAu alloys was performed by the optical microscopy and SEM-EDS method. Based on the microstructural analysis, the existence of all expected phases was confirmed: solid

solutions based on copper, aluminum and gold (Cu, Al, Au), β and γ phases, as well as the intermetallic compounds AuAl_2 , Al_2Cu , AlCu .

The importance of the obtained results is reflected in the scientific contribution to a better knowledge of the CuAlAu alloys and the assessment of their application in medicine, electronics, electrical engineering, space technology and goldsmithing.

ACKNOWLEDGEMENTS

This work was financially supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia, Contract No. 451-03-68/2022-14/200052.

REFERENCES

- [1] M.B. Cortie, F.C. Levey, Structure and ordering of the 18-carat Al–Au–Cu β -phase, *Intermetallics*, 8 (7) (2000) 793-804.
- [2] F.C. Levey, M.B. Cortie, L.A. Cornish, A 500 °C Isothermal Section for the Al–Au–Cu System, *Metall. Mater. Trans. A*, 33A (2002) 987-993.
- [3] K.-W. Goo, W.-T. Chiu, A. Toriyabe, M. Homma, A. Umise, M. Tahara, K. Goto, T. Sannomiya, H. Hosoda, Mechanical Properties Enhancement of the Au–Cu–Al alloys via Phase Constitution Manipulation, *Materials (Basel)*, 14 (11) (2021) 3122.
- [4] A.I. Kostov, Z.S. Stanojevic Simsic, A.R. Milosavljevic, Physical Chemistry Data of some Alloys in a Cu–Al–Au Ternary System, *J. Phys. Chem. C*, Vol. 125, 43 (2021) 24043–24051.