INTERNATIONAL CONFERENCE

MEĐUNARODNA KONFERENCIJA

MEETING POINT OF THE SCIENCE AND PRACTICE IN THE FIELDS OF CORROSION, MATERIALS AND ENVIRONMENTAL PROTECTION

STECIŠTE NAUKE I PRAKSE U OBLASTIMA KOROZIJE, ZAŠTITE MATERIJALA I ŽIVOTNE SREDINE

PROCEEDINGS

KNJIGA RADOVA

Under the auspicies of the
MINISTRY OF SCIENCE, TECHNOLOGICAL DEVELOPMENT AND INNOVATION OF THE REPUBLIC OF SERBIA

Pod pokroviteljstvom
MINISTARSTVO NAUKE, TEHNOLOŠKOG RAZVOJA I INOVACIJA REPUBLIKE SRBIJE

https://doi.org/10.65614/uisk_yucorr.2026.27

May 25-28, 2026, Vrnjačka Banja, Serbia

CIP - Каталогизација у публикацији Народна библиотека Србије, Београд

620.193/.197(082)(0.034.2)
621.793/.795(082)(0.034.2)
667.6(082)(0.034.2)
502/504(082)(0.034.2)
66.017/.018(082)(0.034.2)

МЕЂУНАРОДНА конференија YuCorr (27 ; 2026 ; Врњачка Бања)
Meeting point of the science and practice in the fields of corrosion, materials and environmental protection [Elektronski izvor] : proceedings = Stecište nauke i prakse u oblastima korozije, zaštite materijala i životne sredine : knjiga radova / XXVII YuCorr International Conference, May 25-28, 2026, Vrnjačka Banja, Serbia = XXVII YuCorr Međunarodna konferencija ; [organized by] Serbian Society of Corrosion and Materials Protection ... [et al.]] = [organizatori Udruženje inženjera Srbije za koroziju i zaštitu materijala ... [et al.] ; [editors, urednici Miroslav Pavlović, Marijana Pantović Pavlović]. - Beograd : Serbian Society of Corrosion and Materials Protection UISKOZAM = Udruženje inženjera Srbije za koroziju i zaštitu materijala UISKOZAM, 2026 (Beograd : UISKOZAM). - 1 elektronski optički disk (CD-ROM) ; 12 cm

Sistemski zahtevi: Nisu navedeni. - Nasl. sa naslovne strane dokumenta. - Radovi na engl. i srp. jeziku. - Tiraž 200. - Bibliografija uz većinu radova. - Abstracts.

ISBN 978-86-82343-34-9

a) Премази, антикорозиони -- Зборници b) Превлаке, антикорозионе -- Зборници
v) Антикорозиона заштита -- Зборници g) Животна средина -- Заштита -- Зборници
d) Наука о материјалима -- Зборници

COBISS.SR-ID 196491017

XXVII YUCORR – International Conference | *Međunarodna konferencija*

PUBLISHED BY | *IZDAVAČ*
SERBIAN SOCIETY OF CORROSION AND MATERIALS PROTECTION (UISKOZAM)
UDRUŽENJE INŽENJERA SRBIJE ZA KORZIJU I ZAŠTITU MATERIJALA (UISKOZAM),
Kneza Miloša 7a/II, 11000 Beograd, Srbija, tel/fax: +381 11 3230 028, *office@uiskozam.rs; www.uiskozam.rs*

FOR PUBLISHER | *ZA IZDAVAČA* *Dr MIROSLAV PAVLOVIĆ, predsednik UISKOZAM*

EDITORS | *UREDNICI:* *Dr Miroslav Pavlović, Dr Marijana Pantović Pavlović*
SCIENTIFIC AREA | *OBLAST:* CORROSION AND MATERIALS PROTECTION **|** *KOROZIJA I ZAŠTITA MATERIJALA*
PAGE LAYOUT | *KOMPJUTERSKA OBRADA I SLOG:* *Dr Marijana Pantović Pavlović*
DOI OBTAINED BY | *DOI BROJEVI:* *Studio Grma, Nikole Lunjevice 3D, 32300 Gornji Milanovac*
CIRCULATION | *TIRAŽ:* **200** copies **|** *primeraka*
REPRODUCER | *UMNOŽAVA:* UISKOZAM
PUBLICATION YEAR | *GODINA IZDANJA:* **2026**
ISBN 978-86-82343-34-9

Synthesis : : Materials : : Corrosion : : Environment : : Energy

XXVII YuCorr

Analyse : : Discover : : Coat : : Green : : Protect : : Save : : Sustain

May 25-28, 2026, Vrnjačka Banja, Serbia

Ovaj PDF fajl sadrži elektronsku Knjigu radova prezentovanih u okviru Međunarodne konferencije **XXVII YuCorr.** U knjizi su **plavom bojom** obeleženi aktivni linkovi ka pojedinim njenim delovima, iz Sadržaja do naznačenih stranica.

This PDF file contains Proceedings presented on the **XXVII YuCorr** International Conference. It can be easily navigated through the book contents by a single click on the appropriate links in Contents (**showed in blue**).

Autori snose punu odgovornost za sadržaj, originalnost, jezik i gramatičku korektnost sopstvenih radova.

Authors bear full responsibility for the content, originality, language and grammatical correctness of their own works.

XXVII YUCORR IS ORGANIZED BY
ORGANIZATORI XXVII YUCORR-a

SERBIAN SOCIETY OF CORROSION AND MATERIALS PROTECTION

Udruženje Inženjera Srbije za Koroziju i Zaštitu Materijala

INSTITUTE OF CHEMISTRY, TECHNOLOGY AND METALLURGY, UNIVERSITY OF BELGRADE

Institut za Hemiju, Tehnologiju i Metalurgiju, Univerzitet u Beogradu

INSTITUTE OF GENERAL AND PHYSICAL CHEMISTRY, BELGRADE

Institut za Opštu i Fizičku Hemiju

UNION OF ENGINEERS AND TEHNICIANS OF SERBIA, BELGRADE

Savez Inženjera i Tehničara Srbije

ENGINEERING ACADEMY OF SERBIA

Inženjerska Akademija Srbije

XXVII YUCORR IS ORGANIZED UNDER THE AUSPICIES OF THE

MINISTRY OF SCIENCE, TECHNOLOGICAL DEVELOPMENT AND INNOVATION OF THE REPUBLIC OF SERBIA

XXVII YUCORR JE FINANSIJSKI POMOGLO

MINISTARSTVO NAUKE, TEHNOLOŠKOG RAZVOJA I INOVACIJA REPUBLIKE SRBIJE

GOLD SPONSOR | *ZLATNI SPONZOR*

JADRAN d.o.o., Beograd

SILVER SPONSORS | *SREBRNI SPONZORI*

MC Labor d.o.o., Beograd

Krug International Ltd. Malta, Ogranak Krug Beograd, Beograd

WELCOME COCTAIL SPONSORS | *SPONZORI KOKTELA DOBRODOŠLICE*

KEFO d.o.o., Beograd

D&F Trading and Consulting, Majur

SPONSORS | *SPONZORI*

ALFATERM d.o.o., Čačak

INTERNATIONAL SOCIETY OF ELECTROCHEMISTRY, Switzerland

KANSAI HELIOS, Gornji Milanovac

INSTITUT ZA PREVENTIVU d.o.o., Novi Sad

Contents

PLENARY LECTURES
PLENARNA PREDAVANJA

Sustainable recovery of metals from intermediate products

Održivo izdvajanje metala iz međuprodukata

Srecko Stopic[1,*], Dimitrije Anđić[2], Aleksandar Jovanović[2], Marija Simić[2], Miroslav Sokić[2], Željko Kamberović[3], Bernd Friedrich[1]

[1]*Institute for Process Metallurgy and Metal Recycling, RWTH Aachen University, Inzestrasse 3, Aachen, Germany*

[2]*Institute for Technology of nuclear and other mineral raw materials, Bulevar Franš D' Eperea 86, Belgrade, Serbia*

[3]*University of Belgrade, Faculty of Technology and Metallurgy,University of Belgrade, Karnegijeva 4, Belgrade, Serbia*

https://doi.org/10.65614/uisk_yucorr.2026.27.ch1

[*]*sstopic@ime-aachen.de*

Abstract

Fast industrialization and modern life have increased the demand for critical metals such as titanium and rare earth elements. On the other hand, high-grade ore natural reserves are just mosly used and their quantity is decreased. Therefore, alternative sources of valuabled metals such as intermediate products need to be considered and investigated. Massive amounts of industrial wastes are being generated annually in production of aluminium oxide and titanium oxides. The majority is sent to landfills, which eventually poses environmental challenges such as ecological contamination and health hazards to living beings. Such industrial wastes contain various major elements (Fe, Na, Ca, Si, Al, and Ti), whose improper disposal leads to adverse effects to human being and the environment. As a result, hydrometallurgical and pyrometallurgical operations such as leaching, filtration, precipitation, solvent extraction, crystallization and metal winning have received much attention due to the fact that they improve cost effectiveness over time and enable the metal recovery businesses to thrive profitably. This paper provides a state of art review on the current technologies existing for the recovery of titanium from industrial wastes streams to analyse the sustainability. Among the wastes, red mud, electric furnace dust and fly ash are some of the largest metallurgical generated wastes. Various metal recovery processes involve wastes from aluminium and titanium industry aiming separation and extraction of target metals. The current challenges of hydrogen reduction in pyrometallurgy, sustainable hydrometallurgy other advanced technologies such as ultrasonic spray pyrolysis are partially metnioned in this paper. The hydrometallurgical method, which involves dissolving and leaching, is aproven and successful process for recovering metals from ores and concentrates. The limitations placed on waste disposal and stringent environmental legislation require environmental-friendly metal recovery technologies. This review paper provides critical information that enables researchers to identify a proper research strategy for metal recovery from different industrial intermediate products.

Keywords: *titanium; recovery; metals; reduction; hidrometallurgy; pyrometallurgy; intermediate*

Izvod

Brza industrijalizacija i savremeni život povećali su potražnju za kritičnim metalima kao što su titan i elememti retkih zemalja. S druge strane, prirodne rezerve visokokvalitetnih ruda se uglavnom koriste, a njihova količina se smanjuje. Stoga, potrebno je razmotriti i istražiti alternativne izvore vrednih metala, kao što su međuproizvodi. Ogromne količine industrijskog otpada se godišnje stvaraju u proizvodnji aluminijum oksida i titanijum oksida. Većina se šalje na deponije, što na kraju

predstavlja ekološke izazove kao što su ekološka kontaminacija i opasnost po zdravlje živih bića. Takav industrijski otpad sadrži različite glavne elemente (Fe, Na, Ca, Si, Al i Ti), čije nepravilno odlaganje dovodi do negativnih efekata na ljude i životnu sredinu. Kao rezultat toga, hidrometalurške i pirometalurške operacije kao što su luženje, filtracija, taloženje, ekstrakcija rastvaračima, kristalizacija i dobijanje metala dobile su veliku pažnju zbog činjenice da vremenom poboljšavaju isplativost i omogućavaju preduzećima izdvajanje metala da profitabilno napreduju. Ovaj rad pruža pregled najsavremenijih istraživanja, koje postoje za dobijanje titana iz tokova industrijskog otpada kako bi se analizirala održivost. Među otpadima, crveni mulj, prašina iz elektrolučnih peći i leteći pepeo su neki od najvećih otpada koji nastaju u metalurškoj industriji. Različiti procesi dobijanja metala uključuju otpad iz industrije aluminijuma i titana sa ciljem odvajanja i ekstrakcije ciljnih metala. U ovom radu su delimično predstavljeni trenutni izazovi uključivanja redukcije vodonikom u pirometalurgiji, održivoj hidrometalurgiji i drugim naprednim tehnologijama kao što je raspršivanje rastvora u ultrazvučnom polju. Hidrometalurška metoda, koja uključuje rastvaranje i separaciju, je dokazan i uspešan proces za dobijanje metala iz ruda i koncentrata. Ograničenja koja se postavljaju u pogledu odlaganja otpada i strogi propisi o zaštiti životne sredine zahtevaju ekološki prihvatljive tehnologije izdvajanja metala. Ovaj rad pruža ključne informacije koje omogućavaju istraživačima da identifikuju odgovarajuću istraživačku strategiju za dobijanje metala iz različitih industrijskih međuprodukata.

Ključne reči: *titan; izdvanje; metal; redukcija; hidrometalurgija; pirometalurgija; međuproizvod*

Introduction

The industrial production of aluminium oxide and titanium dioxide is associated with the generation of massive volumes of industrial residues that present both environmental challenges and opportunities for resource recovery. Among these, bauxite residues or red mud by-product of alumina production through the Bayer process, and tionite, a residue from titanium dioxide (TiO_2) manufacturing from ilmenite via the sulfate process, represent two of the most significant metallurgical wastes [1]. Their safe disposal remains a pressing global issue, yet their chemical composition and mineralogy also make them promising secondary resources for metal recovery and other industrial applications [2].

Red mud is generated in quantities ranging from 0.5 to 2.0 tons per ton of alumina produced, with global stockpiles estimated to exceed 5 billion tons as of 2020. Its characteristic red color derives from a high iron oxide content, but it also contains residual alumina, silica, titanium dioxide, and alkali oxides. The material is highly alkaline (pH 9–13), which poses serious risks of soil and groundwater pollution, corrosion of infrastructure, and toxicity to ecosystems [3]. Furthermore, its fine particle size makes dusting a challenge in dry storage. Traditionally managed by slurry disposal, dry stacking, or solar drying, red mud continues to be classified as a hazardous material due to its composition and handling requirements. Nevertheless, extensive research has highlighted its potential utilization in applications such as stabilization materials, adsorbents, catalysts, ceramics, pigments, cements, and particularly in the recovery of valuable metals such as iron, aluminum, and titanium [4–5].

Tionite, on the other hand, originates mainly from the sulfate process of TiO_2 production, where undissolved ore residues are separated after leaching, as shown at Figure 1:

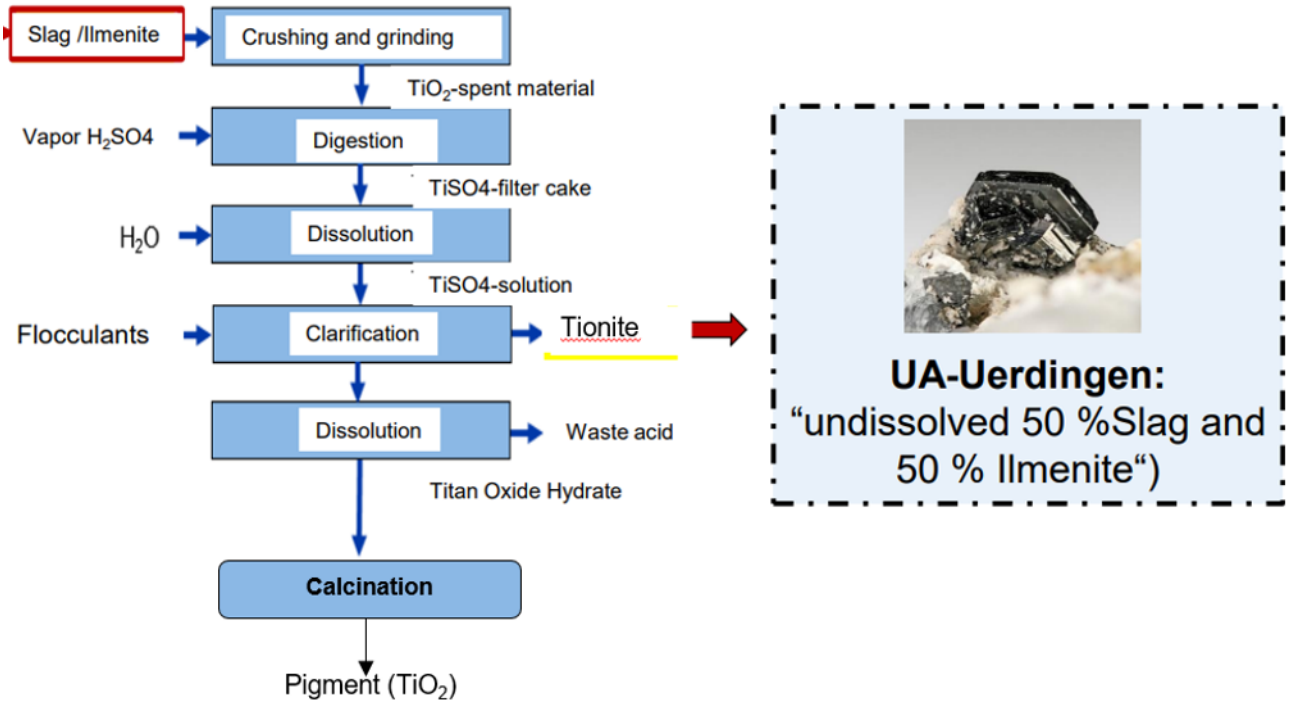


Figure 1. *Formation of tionite during production of titanium oxide using sulphate process.*

These residues are complex, consisting of unreacted titanium compounds, iron oxides, other metal oxides, and often entrapped sulfuric acid. This combination makes tionite both environmentally problematic and difficult to process. While the chloride process also generates titanium-bearing residues, tionite from the sulfate route is particularly abundant. Due to its high TiO_2 content and rutile-dominated mineralogy, tionite represents a potential secondary resource, though its stability makes direct utilization challenging. Approaches investigated for tionite valorization include hydrometallurgical leaching for titanium recovery, pyrometallurgical conversion into titanium-rich slags, reintegration into TiO_2 production, and applications in environmental remediation, construction materials, or catalyst production. Despite these efforts, large-scale solutions remain underdeveloped, and innovative strategies are required to both mitigate environmental risks and unlock its resource potential [6].

A promising pathway for the simultaneous valorization of red mud and tionite is carbothermal reduction [7]. This process enables selective reduction and separation of iron, addressing one of the key obstacles for their utilization. In the case of tionite, the addition of calcium oxide not only acts as a fluxing agent to facilitate reduction but also promotes the formation of calcium titanate, thereby disrupting the stable rutile structure and preparing the residue for downstream processing. For both residues, the reduction step serves as a preparatory stage for subsequent leaching, allowing recovery of valuable metal components while stabilizing the remaining slag.

Our general study focuses on the combined treatment of red mud and tionite using hydrometallurgical and pyrometallurgical method aiming to: (i) remove iron efficiently, (ii) destabilize the stable titanium phases in tionite, and (iii) prepare a leachable slag suitable for further resource recovery such as ultrasonic spray pyrolysis and titanium winning using molten salt electrolysis or aluminothermic reduction, as shown at Figure 2.

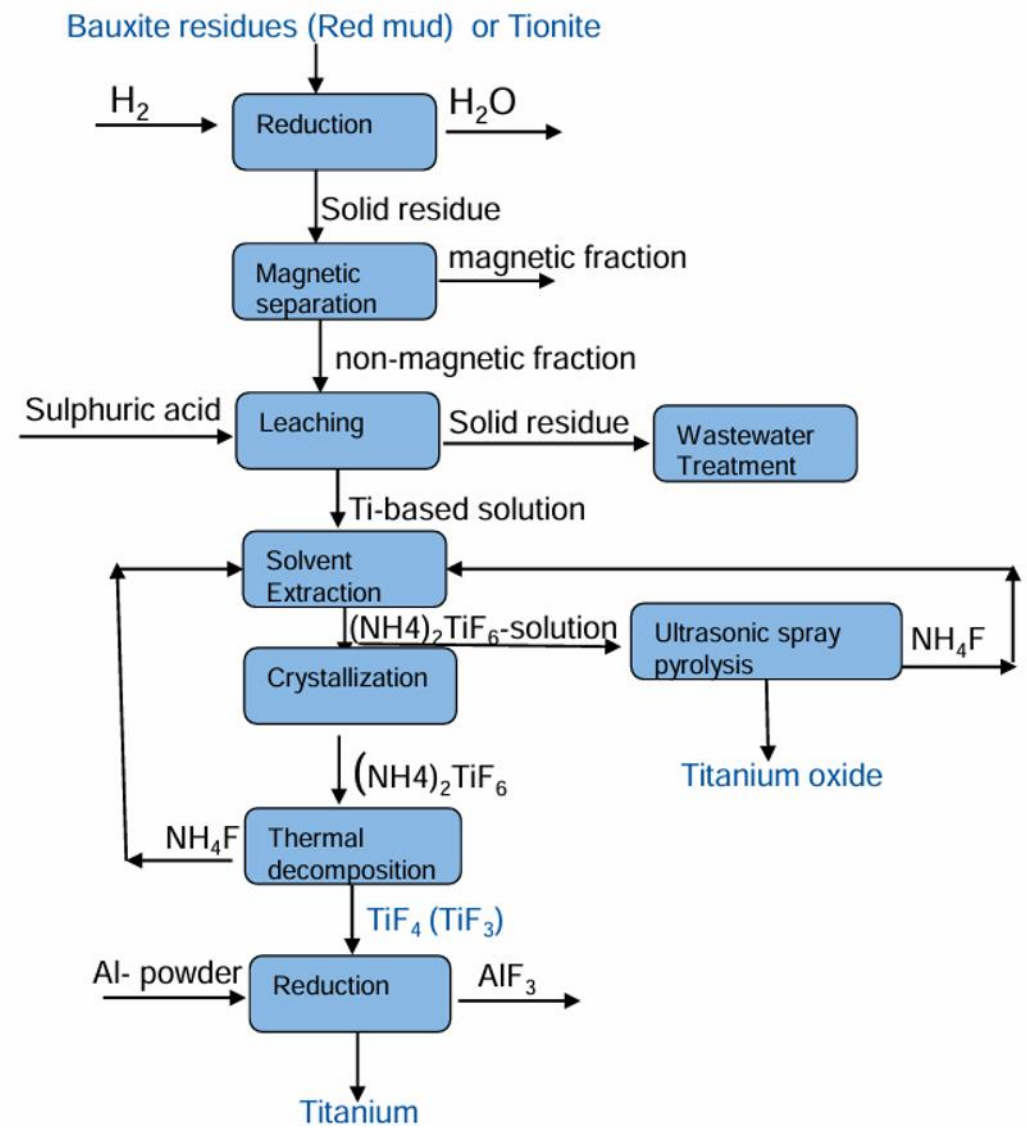


***Figure 2**. Sustainable recovery of metals from intermediate products.*

In our previous work [8] dissolution of red mud and tionite was performed using high pressure leaching conditions, what is very expensive prosess. Because of all this, new investigations were carried out at low temperatures and atmospheric pressure in a glass reactor and are presented here. This paper will be focused on hydrometallurgical treatment of the intermediate from aluminium and titanium industry after pyrometallurgical treatment aiming the transfer of titanium in solution.

Experimental

Material

Different types of materials were used for the leaching under an atmospheric pressure at 90 °C: 1. Tionite (solid residue from Sulfate process for production of titanium oxide) ; 2. MAG.TION.-sample obtained after hydrogen reduction of tionite at 920°C (magnetic fraction); 3. EAF (TION)- tionite after reduction in an electric arc furnace at 1460°C , 4. red mud (dried solid residues after leaching of bauxite with sodium hydroxide in an autoclave in Nova Alumina Zvornik) and 5. Pure titanium oxide produced by VENATOR, Germany. Some used samples were shown at Figure 3.

Figure 3. *The mostly used samples for leaching experiments.*

The chemical analysis of all samples is shown in Table 1.

Table 1. Chemical analysis of samples for leaching under an atmospheric pressure

Elements (%)	Mg	Fe	Ca	Ti	Si	Al
Tionite UA	1.78	5.90	1.95	29.42	25.96	3.06
Magnetic fraction after H_2 reduction (MAG.TION)	1.74	6.10	2.16	27.36	25.43	2.94
Slag after smelting of tionite in an electric arc furnace EAF(TION)	1.41	0.75	13.43	22..68	23.95	2.44
Red mud	0.38	34.50	5.88	2.75	4.90	3.18
Titanium oxide				60		

Stopic et al. [3,5] reported that XRD-analysis of red mud confirms mostly the presence hematite and other very stable oxides such as perovskite, calcite, diaspore, boehmite, anhydride.The sample of tionite shows the presence of dominant phases which are rutile, Mg-Ti oxide, and kennedyite (iron titanium magnesium oxide). Rutile appears to be the dominant phase. The presence of Mg-Ti oxide suggests the formation of a complex phase that could influence the reactivity of titanium during leaching. Kennedyite which is a less common phase is also detected.

Experimenal Setup

The experiments were performed using leaching glass reactor with connected thermostat for the regulation temperature in an acidic solution, as shown at Figure 4. Different leaching agents such as sulphuric acid, hydrochloric acid, sodium hydroxide, and metasulfonic acid (MSA) are used at room temperature, 50°C and 90 °C using different solid/liquid ratio in duration of 4 and 6 hours.

Figure 4. *Experimental setup for the leaching experiments.*

After leaching experiments the suspension was filtrated using the equipment, as shown at Figure 5.

Figure 5. *Experimental setup for the filtration experiments.*

ICP-OES Agilent 5000 ICP-OES equipped with advanced features for enhanced performance was used for analysis of solid and liquid. This system is very efficient and known for high sensitivity and wide dynamic range, detecting and quantificating not just major but also trace elements. Advanced optics and detector technology ensure reliable and reproducible results for almost every element. EDS analysis was performed using an Octane Plus-A detector by Ametek-EDAX. This detector is very popular and has high-resolution capabilities and sensitivity, making it suitable for detailed elemental analysis.

Experimental parameters

Two experimental set were performed and presented in Table 2 and 3. The influence of concentration of leaching agent and reaction temperature on the leaching efficiency of different samples was analysed in first set of experiment. In the second set of experiment the influences of solid/liquid ratio was additionally analyzed in order to improve the leaching efficiency.

Table 2. First set experiments performed using 50 g in 1L solution in 6 hours

Exp. Number	Sample	Concentration of leaching agent (mol/L)	T (°C)
1.	EAF (TION)	2.5 H_2SO_4	90
2.	EAF (TION)	2.5 HNO_3	90
3.	EAF (TION)	5.0 NaOH	90
4.	EAF (TION)	2.5 MSA	25
5.	TiO_2	2.5 H_2SO_4	90
6.	MAG.TION.	2.5 H_2SO_4	50
7.	MAG.TION.	2.5 HNO_3	50
8.	MAG.TION.	2.5 MSA	90
9.	TIONITE	2.5 H_2SO_4	90
10.	TIONITE	2.5 HNO_3	90
11.	TIONITE	2.5 MSA	90
12.	MAG.TION.	3.0 HNO_3	90
13.	TiO_2	1.0 M HCl	90

Table 3. Second set experiments performed at 90 °C in 6 hours

Exp. Number	Sample	Concentration of leaching agent (mol/L)	Mass of sample (g)
1.	EAF (TION)	1.0 HCL	50
2.	EAF (TION)	1 H_2SO_4	50
3.	EAF (TION)	1 H_2SO_4	25
4.	MAG.TION.	1 H_2SO_4	50
5.	TIONITE	1 H_2SO_4	50
6.	MAG.TION	2.5 H_2SO_4	25
7.	EAF (TION)	2.5 HCl	50
8.	MAG.TION	2.5 HCL	50
9.	TIONITE	2.5 HCl	50
10.	EAF (TION)	2.5 HCl	25
11.	MAG.TION	2.5 HCl	6

Results and Discussion

The obtained results for leaching efficiency of different samples were presented at Figure 6.

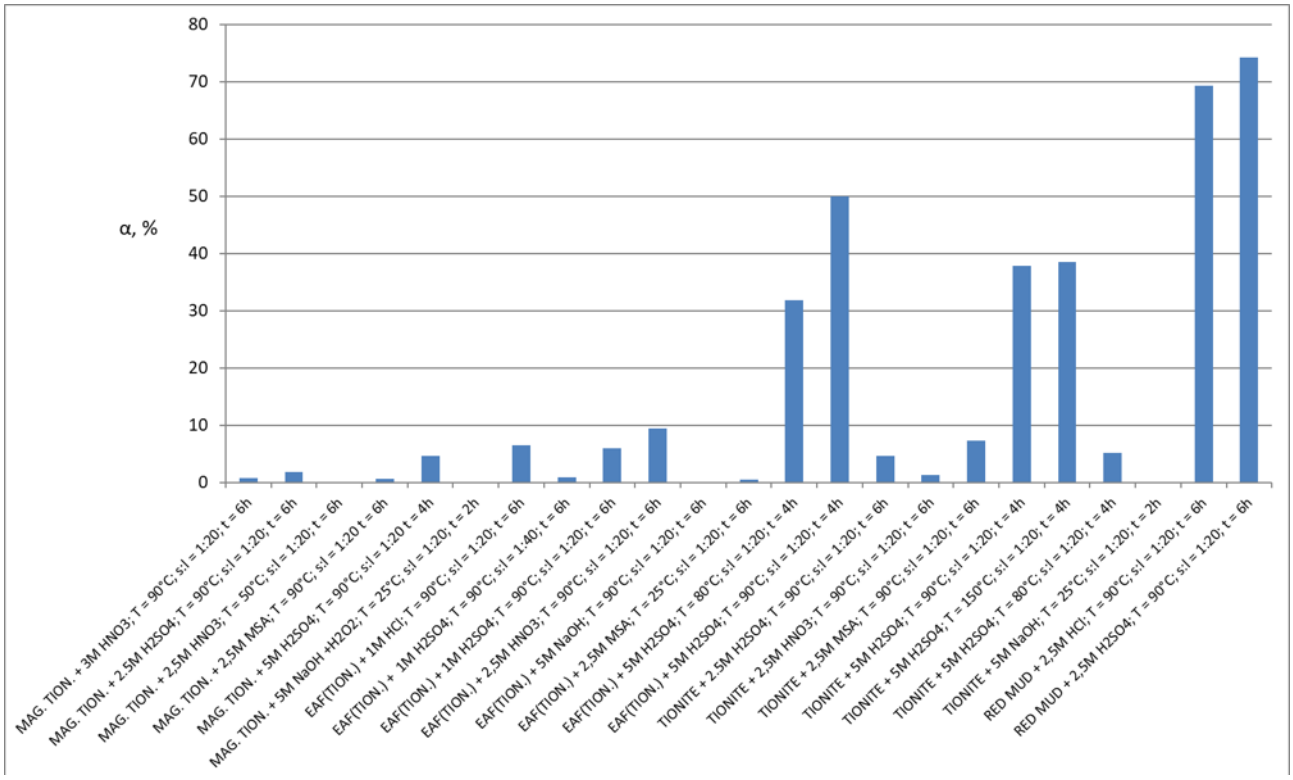


Figure 6. *Leaching efficiency of titanium for different samples.*

Based on the obtained results of leaching of the initial samples in the specified systems, tiitanium oxide is not soluble under an atmospheric pressure at room temperature and 90 °C. The best titanium leaching results were achieved during the leaching of red mud in HCl (69.3%) and H_2SO_4 (74.3%) at 90 °C in 6 hours. Lower, yet still significant titanium leaching results were achieved under the following conditions:

- EAF (TION) + 5M H_2SO_4; T = 90 °C; s:l = 1:20; t = 4h (49.9%);
- TIONITE + 5M H_2SO_4; T = 150 °C; s:l = 1:20; t = 4h (38.5%);
- TIONITE + 5M H_2SO_4; T = 90 °C; s:l = 1:20; t = 4h (37.8%);
- EAF (TION) + 5M H_2SO_4; T = 80 °C; s:l = 1:20; t = 4h (31.8%)

It was observed that temperature significantly affects the leaching degree, as confirmed by the presented results. The presence of very stable titanium oxide (rutile) in tionite is main reason for unsufficient leaching efficiency. Formation of new Ti-bearing phases (pseudobrookite, perovskite, titanite) demonstrates the impact of CaO and reduction in altering the rutile structure, what is suitable for the leaching process [5]. The use of methanesulfonic acid and sodium hydroxide showed poor dissolution of titanium from the samples. The most optimal solid/liquid ratio for dissolution is 1:20.

Conclusion

The obtained results confirm that the best dissolution of red mud is by cutting sulfuric acid to 90% in 6 hours. The LEAST dissolution is for pure titanium oxide. The conversion of titanium oxide during reduction processes leads to an increase in the efficiency of extraction due to the conversion of titanium into soluble forms. However, these results are lower than those obtained due to high pressures in the autoclave at 150°C. In general, the use of sulfuric acid gives the best results of dissolving titanium and various samples in relation to the use of hydrochloric acid, nitric, and metasulfonic acid.

By integrating metallurgical and environmental considerations, this work contributes to the development of sustainable strategies for the utilization of these major industrial intermediate products.

Acknowledgements

This research was funded by the European Commission, grant number 101135077 (EURO-TITAN project). We would like to DAAD (German Academic Exchange Service) and Ministry of Science, Technological Development and Innovation of the Republic of Serbia for the funding of the project „Recovery of titanium from bauxite residue", Project ID-57750094.

References

1. Rai S, Bahadure S, Chaddha MJ, Agnihotri A. Disposal Practices and Utilization of Red Mud (Bauxite Residue): A Review in Indian Context and Abroad. Journal of Sustainable Metallurgy 2020;6:1–8.
2. Gázquez MJ, Bolívar JP, García-Tenorio García-Balmaseda R, Vaca F. A review of the production cycle of titanium dioxide pigment. Materials Sciences and Applications 2014;05:441–458.
3. Stopic, S., Kostic, D., Nikolic, N., Zivotic, D., Rosic, M., Perusic, M., Friedrich B, Production of titanium dioxide nanopowders from red mud, Bulletin of Mines 2025, 1903, 1-28.
4. Liu Y, Naidu R. Hidden values in bauxite residue (red mud): Recovery of metals. Waste Management 2014;34:2662–2673.
5. Stopić, S, Kostić, D., Perušić, Wegmann, F, Nikolić, N, Friedrich, B, Carbothermal reduction of residues of bauxite (red mud) and ilmenite (tionite): a sustainable approach to resource recovery, Bulletin of mines, 2026, 51-62
6. Liu Y, Naidu R. Hidden values in bauxite residue (red mud): Recovery of metals. Waste Management 2014;34:2662–2673.
7. Stopic, S., Schneider, R., Kostić, D., R. Souza Filho, I., Perusic, M., Mitrasinovic, A., Bernd Friedrich, B., Comparative Analysis of Reduction Techniques Aiming for the Minimization of Contaminated Soil with Red Mud, Minerals 2025, 15, 470 https://doi.org/10.3390/min15050470.
8. Stopic, S., Kostic, D., Emil-Kaya, E., Uysal, E., Gürmen, S., Mitrašinovic, A., Perušic, M, Friedrich, B, High-Pressure and High-Temperature Dissolution of Titanium from Titanium and Aluminum Residues: A Comparative Study, Surfaces 2024, 7, 1096–1108. https://doi.org/10.3390/surfaces7040072.

Use of biotechnological methods to obtain bioenergy and PHA biopolymers from organic sources

Otton Roubinek*

Łukasiewicz–Industrial Chemistry Institute, Department of Pharmacy, Cosmetic Chemistry and Biotechnology, Warsaw, Poland

**otton.roubinek@ichp.lukasiewicz.gov.pl*

Abstract

Current technological development and progress, as well as difficulties related to the supply of fossil fuels, mean that the possibility of obtaining energy from renewable sources can be used to they diversify. Energy consumption is growing, and its availability is crucial for the functioning of our society. However, it may become a challenge in the future, as access to resources such as natural gas, coal, and crude oil can be difficult and limited, therefore highlighting the need for diversification and the development of new methods of obtaining energy based on local resources are important. Biomass, agricultural waste, and food industry waste containing organic carbon can be utilized for this purpose. These compounds can be used to obtain biofuels, raw materials for the chemical industry, and the production of biodegradable biopolymers. Biotechnological methods enable the processing of waste and biomass into biofuels and biopolymers using microorganisms and enzymes. These methods are low temperature, but the processes involved are longer and require the application of appropriate knowledge and technology. These methods are used in environmental protection, the food and pharmaceutical industries, and others to produce active substances and biopolymers, which, depending on their type and properties, can be used to produce biodegradable packaging and medical implants. Biopolymers can be of natural origin or synthesized by microorganisms, which include microbially synthesized biopolymers Polyhydroxyalkanoates (PHAs). In the case of renewable sources they derived from wind and solar energy depends on the season and weather. A stable source of renewable energy is the processing of organic waste in biogas plants through methane fermentation or co-fermentation, particularly in agricultural biogas plants, which can contribute to the development of rural areas and the production of natural fertilizers for agriculture. This represents a development opportunity for countries with developed agriculture, a food industry, and access to biomass.

Intriguing Aspects of of Oxygen Evolution Electrocatalyst Dissolution: Towards Stability Descriptors

Intrigantni aspekti rastvaranja elektrokatalizatora za izdvajanje kiseonika: korak prema deskriptorima stabilnosti

Aleksandar R. Zeradjanin*

Max Planck Institute for Chemical Energy Conversion, Scientific Infrastructure – Electrochemistry Stiftstrasse 34-36, 45470 Mülheim an der Ruhr, Germany

https://doi.org/10.65614/uisk_yucorr.2026.27.ch2

**aleksandar.zeradjanin@cec.mpg.de*

Abstract

Widespread deployment of sustainable energy technologies is facing limitations due to relatively low efficiency of key energy conversion processes:conversion of renewable energy to electricity, conversion of renewable electricity to chemical energy as well as re-conversion of chemical energy to electricity. One of the essential technologies to convert renewable electricity to chemical energy is water electrolysis. Despite being a topic of investigation for decades, water electrolysis still conceals too many unknowns related to reaction mechanism. That could be the main underlying reason for too many obstacles on the pathway to enhance water electrolysis efficiency. Conversion process is based on two electrocatalytic reactions: facile hydrogen evolution reaction (HER) at the cathode and sluggish oxygen evolution reaction (OER) at the anode. OER is additionally related to severe anode stability issues and therefore it is nowadays more frequently studied. Widely accepted approach to enhance performance of OER anodes is to search for more active electrode materials, while issues related to electrode stability are very often disregarded. Besides gas evolution that has destabilizing effect on electrode surface morphology, very often is lacking significant input to better understanding of intrinsic drivers of electrocatalyst stability. Enhancement of OER anode stability requires existence of straightforward structure-stability relations. In that way, it is possible to tune material properties and interfacial properties of electrode/electrolyte boundary, to achieve long term electrocatalytic performance. Practical precondition for creating link: material properties – interfacial properties – reaction kinetics is to have advanced analytical tools that will allow relevant view on reaction mechanism. Therefore, in this work we propose discussion that will analyse several key aspects of electrode stability in relation to OER electrocatalysis with special focus on what are relevant stability descriptors. Experimental data are gathered using: high-temperature rotating disc electrode (RDE) measurements and scanning flow cell with inductively coupled plasma mass spectrometer (SFC-ICPMS).

Keywords: *oxygen evolution reaction; stability descriptor, activation energy, preexponential factor, compensation effect*

Izvod

Široka primena tehnologija održive energije suočava se sa ograničenjima zbog relativno niske efikasnosti ključnih procesa konverzije energije: pretvaranja obnovljive energije u električnu energiju, pretvaranja obnovljive električne energije u hemijsku energiju, kao i ponovne konverzije hemijske energije u električnu energiju. Jedna od ključnih tehnologija za pretvaranje obnovljive električne energije u hemijsku energiju jeste elektroliza vode. Iako je predmet istraživanja već decenijama, elektroliza vode i dalje skriva previše nepoznanica povezanih sa mehanizmom reakcije. To je verovatno glavni razlog brojnih prepreka na putu ka povećanju efikasnosti elektrolize vode. Proces konverzije zasniva se na dve elektrokatalitičke reakcije: brzoj reakciji izdvajanja vodonika

(HER) na katodi i sporoj reakciji izdvajanja kiseonika (OER) na anodi. OER je dodatno povezana sa problemima stabilnosti anode i zato se danas češće proučava. Opšteprihvaćen pristup unapređenju performansi OER anoda jeste potraga za aktivnijim elektrodnim materijalima, dok se pitanja stabilnosti elektroda vrlo često zanemaruju. Pored izdvajanja gasa, koje destabilizuje morfologiju površine elektrode, često nedostaje značajan doprinos boljem razumevanju unutrašnjih pokretača stabilnosti elektrokatalizatora. Unapređenje stabilnosti OER anode zahteva postojanje jasnih odnosa između strukture elektrode/elektrokatalizatora i stabilnosti. Na taj način moguće je prilagoditi osobine materijala i međupovršinske osobine granice elektroda/elektrolit kako bi se postigle dugotrajne elektrokatalitičke performanse. Praktični preduslov za uspostavljanje veze: osobine materijala – međupovršinske osobine – kinetika reakcije jeste posedovanje naprednih analitičkih metoda koje omogućavaju relevantan uvid u mehanizam reakcije. Stoga u ovom radu predlažemo diskusiju koja će analizirati nekoliko ključnih aspekata stabilnosti elektroda u odnosu na OER elektrokatalizu, sa posebnim fokusom na relevantne deskriptore stabilnosti. Eksperimentalni podaci prikupljeni su korišćenjem merenja rotirajuće disk elektrode na visokim temperaturama (RDE) i protočne ćelije za skeniranje povezane sa masenim spektrometrom sa induktivno spregnutom plazmom (SFC-ICPMS).

Ključne reči: *reakcija izdvajanja kiseonika; deskriptor stabilnosti, energija aktivacije, predeksponencijalni faktor, kompenzacioni efekat*

Introduction

One of the central challenges in modern electrocatalysis is understanding and improving the stability of oxygen evolution reaction (OER) electrocatalysts.[1] While certain progress has been achieved in comprehension and enhancement of electrocatalytic activity, long-term stability remains a major obstacle preventing large-scale implementation of water electrolysis technologies for sustainable hydrogen production.[2] Electrocatalyst degradation, including dissolution phenomena occurring prior and during OER under highly oxidative anodic conditions, is still insufficiently understood despite decades of research. This is of essential importance in acidic environments particularly relevant for proton exchange membrane (PEM) electrolyzers, where only a limited number of noble-metal-based materials such as Ir- and Ru-based oxides exhibit sufficient activity. Unfortunately, these materials also suffer from dissolution and structural degradation during operation.[3]

Generally perception in the community is that electrocatalyst activity and stability are intrinsically interconnected and often inversely related. Highly active electrocatalysts tend to be less stable because the same electronic properties that facilitate oxygen evolution also promote oxidation and dissolution of the electrocatalyst surface. This trade-off, if more universal, will complicate the search for higly active and stable electrocatalysts. It is the fact that trade-off is especially pronounced for Ru-based materials, which display excellent OER activity but poor durability, however Au is example where electrocatalytically less active material exhibits also poor stability. Therefore, meaningful understanding of dissolution processes is necessary and only became possible recently with the development of advanced in situ and in operando characterization techniques. In particular, the coupling of scanning flow cells with inductively coupled plasma mass spectrometry (SFC-ICPMS) represented a major breakthrough. This advanced experimental approach allows real-time monitoring of metal dissolution under dynamic electrochemical conditions with extremely high sensitivity and with possibility to explore multitude of parameters relevant for kinetics of OER and dissolution kinetics. Unlike conventional post-mortem analysis, SFC-ICPMS enables differentiation between transient dissolution events and stationary dissolution processes. Such distinction is essential because catalyst degradation is often highly dynamic and strongly dependent on electrochemical history. Using SFC-ICPMS, it was investigated how numerous experimental variables affect dissolution kinetics laying foundation to understand what material propeorties and interfacial properties could play a role of relevant stability descriptors.

Results and Discussion

1. Place Exchange as Potential-Triggered Transient Process

Numeorus parameters, that are relevant for catalyst stability/dissolution, were investigated in the literature, including: electrode potential, potential scan direction, polarization time, electrolyte composition, pH, dissolved gases, temperature, catalyst loading, particle size, and interparticle distance as well as and electrolyte composition including additives and impurities. Among these factors, applied potential emerges as variables unique for electrocatalytic reactions. Increasing anodic potential generally accelerates oxide formation and promotes dissolution, although the exact mechanism depends strongly on the nature of the electrocatalyst and electrolyte environment. Dissolution rates are often highest during oxidation and reduction transitions rather than under steady-state OER operation what droves particular attention to transient dissolution phenomena occurring during potential cycling.[4] During anodic polarization, surface oxidation can destabilize metal atoms and facilitate their release into the electrolyte. Conversely, cathodic reduction of oxide layers may also trigger dissolution because unstable intermediate oxidation states are formed. This dynamic behavior demonstrates that catalyst degradation cannot be understood solely through equilibrium thermodynamics but instead requires detailed kinetic analysis and dynamic conceptual framework.
On that line of thought important concept is the continuous structural reconstruction of electrocatalyst surfaces prior and during OER. Under operational conditions, many catalysts do not preserve their original structure but instead transform into new oxide or oxyhydroxide phases. Consequently, the catalytically active state often differs substantially from the initially synthesized material. One of the essential reasons for electroctalyst dissolution is mechanism of oxide growth known as place exchange mechanism. It is phenomena where oxygen containing adsorbed species penetrate at the subsurface of oxidized metal pushing out surface metal atoms from equilibrium positions, practically causing lattice distortion making surface metal atoms to be more prone to dissolution. Place exchange mechanism is illustrated in Figure 1.

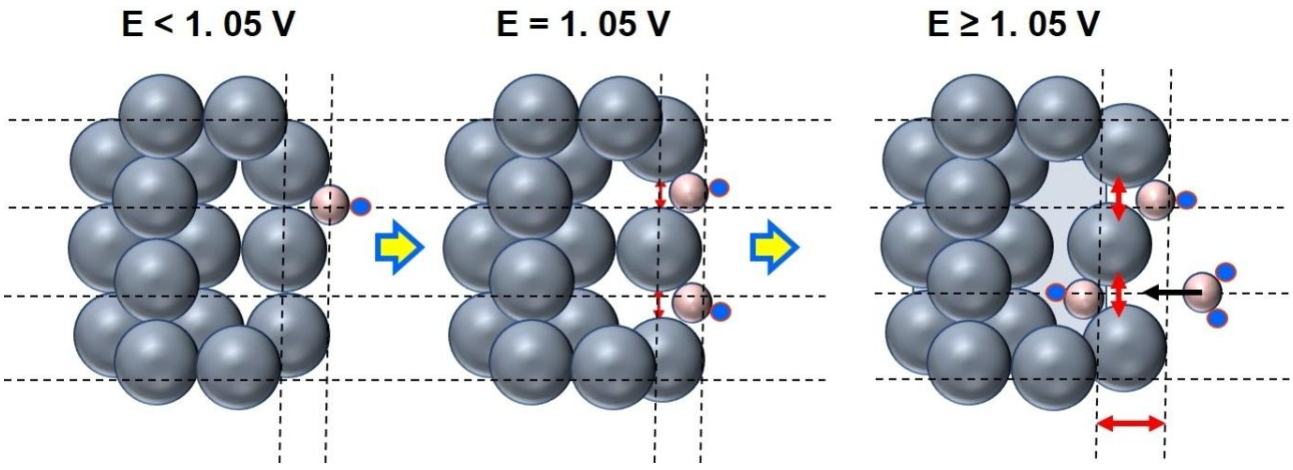


Figure 1. *Illustration of the so called "place-exchange" model of oxide growth that causes lattice instability. Adapted from Ref.4 with permission from Wiley, under the terms and conditions of the Creative Commons Attribution license 4.0 International (2024).*

Namely, when we increse anodic potential, simlutaneously we increase coverage with the adsorbed oxygen-containing species, including signifficant number of M-OH or M-O dipoles in mutual proximity. Formed dipoles exhibit strong electrostatic repulsion and when applied anodic potential is sufficiently high to establish critical coverage at the surface, in order to minimize electrostatic repulsion, oxygen species will migrate at subsurface distorting the lattice by displacing surface metal atoms from their equilibrium positions. Place exchange mechanism as well as other oxide growth

mechanisms, together with phenomena of passivity and transpassivity, represent some of the most important areas o knowledge that will help us reaching of sufficient understanding of electrocatalyst stability.

2. What Could Be Relevant Stability Descritpors?

Taking into consderaiton that coverage with adsorbed oxygen-containing species is driving force for place-exchange while rigidness of the lattice (i.e. that can be described with cohesion energy), is resistive force to place-exchange, we could expect that interplay between M-O (i.e. or M-OH) bond strength and cohesion energy will determine dissolution rate. Noble metals including Pt, Pd, Ir, Ru, Rh, and Au are compared in terms of dissolution behavior. The expectation was that stronger cohesive energy should suppress dissolution because a more strongly bound metal lattice would resist structural distortion. Similarly, stronger metal–oxygen interactions were expected to enhance oxygen adsorption and potentially promote oxide formation and dissolution. However, the experimentally observed trends proved far more complex than anticipated. One of the surprising findings discussed is that dissolution behavior cannot be explained solely by simple correlations with cohesive energy. It seems that dissolution behavior was much more impacted by M-O bond strength as surface property while cohesion energy as bulk property played much less signifficant role.

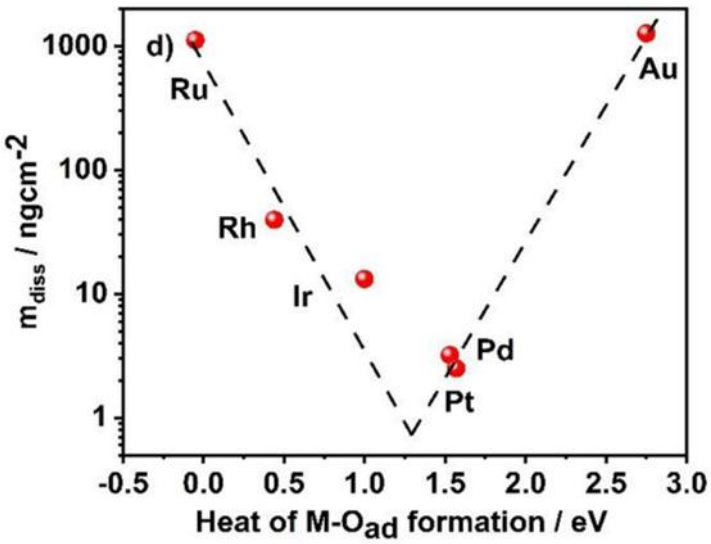


Figure 2. *Correlation of the amount of dissolved metals (Pt, Pd, Ir, Ru, Rh and Au) in 0.1 M $HClO_4$ under galvanostatic polarization at 1 mA cm^{-2} with heat of M−O_{ad} formation. Adapted from Ref.4 with permission from Wiley, under the terms and conditions of the Creative Commons Attribution license 4.0 International (2024).*

From existing results it seems that descriptor of electrocatalyst stability, like in a case of OER activity, could be M-O bond strength. Relation shown in Figure 2 indicates optimal M-O binding that seems to be equivalent to “volcano”-apex in a case of OER acitivty. How close are the value of M-O bond strength at activity maximum and the value of M-O bond strength at stability maximum, still needs to be evalueted experimentally. That information will help us to have better insight how to enhance further activity without comprimising stability.

3. Importance of the Preexponential Frequency Factor in Understanding of Electrocatalyst Stability

High-temperature rotating disk electrode (HT-RDE) experiments reveal that catalyst degradation mechanisms can fundamentally change with temperature. For e.g. Pt dissolution exhibits nearly zero

apparent activation energy yet proceeds very slowly, whereas Ir and Au display much higher dissolution rates despite different activation energies. Furthermore, activation energies often increase alongside dissolution rates, contradicting conventional expectations. These findings indicate that kinetic frequency factors and dynamic surface processes dominate dissolution behavior.

An especially important and intriguing aspect of this work is the discussion of activation energy and the preexponential factor in dissolution kinetics. Experimental results on OER anode dissolution indicate that reducing of activation energy of dissolution process is not necessarily beneficial for enhancement of OER anode stability. Namely, dissolution rates are strongly influenced by preexponential frequency factor. However, because OER electrocatalysts operate under continuously changing surface conditions, both kinetic parameters may vary significantly during operation.

The study demonstrates that dissolution rates can exhibit compensation effects, meaning that variations in activation energy are often accompanied by compensating changes in the preexponential factor. As a result, two catalysts with similar apparent activation energies may display vastly different dissolution behaviors.[5] This finding suggests that simplistic interpretations based solely on thermodynamic descriptors may be insufficient for predicting catalyst durability. Instead, a more comprehensive kinetic framework is required to understand degradation mechanisms. Consequently, stability assessments performed only at room temperature may fail to accurately predict catalyst performance under industrial operating conditions.

Conclusion

Work emphasize that electrocatalyst dissolution occurs on continuously reconstructing surfaces rather than static interfaces. Consequently, conventional kinetic models such as Butler–Volmer equation cannot adequately describe dissolution behavior. Instead, dissolution kinetics is strongly influenced by factors such as proton concentration, active site availability, surface coverage, and dynamic restructuring processes. Therefore, of major importance is to consider how parameters describing interfacial dynamics like collision frequency as well as interplay between activation energy and preexponential factor contribute to reaction kinetics. In that way we could comprehend how activity and stability relate and what are the relevant stability descriptors that can play major role in advanced electrocatalyst design.

Acknowledgements

Financial supports of Serbian Society for Corrosion and Materials as well as Max Planck Society are gratefully acknowledged.

References

1. A.R. Zeradjanin, J. Masa, I. Spanos, R. Schloegl, Activity and Stability of Oxides During Oxygen Evolution Reaction - From mechanistic controversies toward relevant electrocatalytic descriptors, *Frontiers in Energy Research,* **8**, 613092, 2020.
2. A.R. Zeradjanin, The era of stable electrocatalysis, *Nature Catalysis,* **6**, 458, 2023
3. A.R. Zeradjanin, P. Narangods, I. Spanos, J. Masa, R. Schloegl, How to minimise destabilising effect of gas bubbles on water splitting electrocatalysts? *Current Opinion in Electrochemistry,* **30**, 100797, 2021
4. A.R. Zeradjanin, A. Lim, I. Spanos, J. Masa, What limits conquest of stability descriptors? – intriguing aspects of dissolution of oxygen evolution electrocatalysts, *ChemElectroChem* **11**, e202300832, 2024
5. A.R. Zeradjanin, Beyond current frontiers of electrocatalysis, *Journal of Electrochemical Science and Engineering,* **15**, 2634, 2025

INVITED LECTURES
PREDAVANJA PO POZIVU

Assessment of ship recycling potential considering corrosion damage during the projected service life

Procjena reciklažnog potencijala brodova uzimajući u obzir oštećenja od korozije tokom projektovanog životnog vijeka

Aleksandar Mandić, Špiro Ivošević*

University of Montenegro, Faculty of Maritime Studies, Kotor, Montenegro

**spiroi@ucg.ac.me*

Abstract

During an estimated life cycle of 25 years, ships are exposed to dynamic cargo operations and aggressive marine environments, resulting in corrosion, which is becoming one of the most significant problems in the maritime industry. Corrosion processes over time lead to the degradation of the ship's structural elements, through a reduction in thickness and structural strength. Such changes affect not only the structural integrity of the ship but also its circularity and recycling potential, considering that corrosion processes lead to a reduction in the total mass of the ship.

A very important segment of the maritime industry is the ship recycling industry. The Asian continent dominates the ship recycling sector, where India, China, Pakistan, Bangladesh and Turkey stand out as the leading countries in terms of annual gross tonnage of scrapped vessels. The importance of recycling and aspects of safety, environmental protection and working conditions are also recognized by the Hong Kong Convention, which has become mandatory at the global level since 2025.

By applying the Ultrasonic method of measuring the thickness of the structural elements of the ship's hull, in accordance with the prescribed rules of the classification societies, a database was created on the reductions in the thickness of the structural elements of 12 ships for the transport of bulk cargo and 10 ships for the transport of general cargo, as well as the cumulative amounts of replaced steel. By comparing the amounts of replaced steel, the paper evaluates the impact of corrosion and corrosion processes on the recycling potential of ships. The second part of the research refers to the calculation of the amount of steel that is replaced on ships during their operational life, and how much of the reduced DWT, i.e., the recycling potential of bulk carrier ships, is caused by corrosion processes.

The results of the research showed that more worn and damaged elements of the ship's structure were recorded on ships for the transport of bulk cargo compared to general cargo ships, and that the recycling potential and circularity of the bulk carrier were lower. Also, the analyses showed that depending on the position of the elements in the ship's structure, wear and tear and the reduction of DWT can reach up to 15%.

Keywords: *ships; corrosion; recycling*

Izvod

Tokom procjenjenog životnog ciklusa od 25 godina, brodovi su izloženi dinamičnim operacijama sa teretom i agresivnom morskom okruženju, usljed čega dolazi do korozije koja postaje jedan od najznačajnijih problema u pomorskoj industriji. Korozioni procesi tokom vremena dovode do degradacije strukturnih elemenata broda, kroz smanjenje debljine i strukturne čvrstoće. Ovakve promjene ne utiču samo na strukturni integritet broda, već i na njihovu cirkularnost i reciklažni potencijal, uzimajući u obzir da korozioni procesi dovode do smanjenja ukupne mase broda.

Veoma bitan segmet pomorske industrije je industrija reciklaže brodova. Azijski kontinent dominira u sektoru reciklaže brodova, gdje se Indija, Kina, Pakistan, Bangladeš i Turska izdvajaju kao vodeće zemlje po godišnjoj bruto tonaži rashodovanih plovila. Značaj reciklaže i aspekata sigurnosti, zaštite

životne sredine i uslova rada, prepoznati su i Honk Konškom kovencijom koja je od 2025 godine postala obavezna na globalnom nivou.
Primjenom ultrazvučne metode mjerenja debljine strukturnih elemenata brodskog trupa, shodno propisanim pravilima klasifikacionih društava, kreirana je baza podataka o smanjenjima debljine strukturnih elemenata 12 brodova za prevoz rasutog tereta i 10 brodova za prevoz generalnog tereta, te kumulativnim količinama zamjenjenog čelika. Upoređujući količine zamjenjenog čelika, u radu se procjenjuje uticaj korozije i korozionih procesa na reciklažni potencijal brodova. Drugi dio istraživanja odnosi se na kalkulaciju količine čelika koja se zamijeni na brodovima u toku eksploatacionog života, te koliko je umanjene DWT-a, tj reciklažnog potencijala bulk carrier brodova izazvano korozionim procesima.
Rezultati istraživanja pokazali su da su veća istrošena i oštećena elemenata brodske konstrukcije zabilježena na brodovima za prevoz rasutog tereta u poređenju sa general cargo brodovima, te reciklažni potencijal i cirkularnost bulk carrier-a manja. Takođe, analize su pokazale da se u zavisnosti od položaja elemenata u brodskoj strukturi, istrošenja i smanjenje DWT – a može dostići i do 15%.

Ključne reči: *brodovi; korozija; reciklaža*

Advances in understanding of the synthesis of gold particles

Napreci u razumevanju sinteza čestica zlata

Srećko Stopić[1,*], Jelena Isailović[2], Svetlana Polavder[2], Nenad Nikolić[3], Zixi Gao[1], Bernd Friedrich[1]

[1]*Institute for Process Metallurgy and Metal Recycling, RWTH Aachen University, Inzestrasse 3, Aachen, Germany*

[2]*Mining Institute Ltd, Batajnički put 2, Zemun, Serbia*

[3]*Institute of Multidisciplinary Research, Kneza Višeslava 1, Belgrade, Serbia*

[*]*sstopic@ime-aachen.de*

Abstract

Gold mining is a large industry segment that is constantly developing and brings huge revenue. Recently, various methods have been developed for recycling gold from waste materials. These methods are based on converting gold into a solution, and obtaining fine gold particles through reduction processes. The size of the gold particles can be controlled by choosing various reaction parameters such as temperature, solution concentration and time. This paper will present the production of gold particles using ultrasonic spray pyrolysis of aqueous solutions of gold chloride and gold nitrate. Spraying of gold-based aqueous solutions will be performed in a hydrogen and neutral atmosphere. The size of the particles and their morphology were analyzed using scanning electron microscopy and energy dispersive spectroscopy. The resulting particles were collected using an electrostatic filter and a wet scrubber. Gold particles obtained at 800°C from gold chloride solution by hydrogen reduction are agglomerated and with particle sizes below 500 nm.

Keywords: *gold; synthesis; reduction; ultrasonic spray pyrolysis*

Izvod

Rudarstvo zlata je veliki industrijski segment koji se stalno razvija i donosi ogroman prihod. U poslednje vreme razvijaju se razne metode za recikliranje zlata iz otpadnih materijala. Ove metode se zasnivaju na prevođenju zlata u rastvor, i dobijanje finih čestica zlata redukcionim procesima. Veličina čestica zlata može biti kontrolisana izborom raznih reakcionih parametara, kao što su temperatura, koncentracija rastvora i vreme. Ovaj rad će predstaviti dobijanje čestica zlata korišćenjem ultrazvučne pirolize vodenih rastvora zlato-hlorida i zlato-nitrata. Raspršivanje vodenih rastvora baziranih na zlatu biće izvođeno u vodoničnoj i neutralnoj atmosferi. Veličina čestica i njihova morfologija je analzirana korišćenjem skenirajuće elektronske mikroskopije i energetski disperzivne spektroskopije. Dobijene čestice su sakupljane korišćenjem elektrostatičkog filtera i mokrim postupkom. Čestice zlata dobijene na 800°C iz rastvora zlato-hlorida redukcijom vodonikom su aglomerisane i sa veličinama ispod 500 nm.

Ključne reči: *zlato; sinteza; redukcija; raspršivanje ultrazvučnom pirolizom*

Optimization of Two-Step Chemical and Electrochemical Desulfurization and Demineralization of Low-Rank Coal from the Bogovina Basin

Katarina Pantović Spajić*, Branislav Marković

Institute for Technology of Nuclear and Other Mineral Raw Materials, 11000 Belgrade, Serbia

**k.pantovic@itnms.ac.rs*

Abstract

This study investigates the optimization of chemical and electrochemical procedures for the desulfurization and demineralization of low-rank coal from the Eastern Field of the Bogovina Basin, characterized by elevated ash and sulfur contents. The research focuses on improving coal quality and reducing environmentally harmful emissions through selective removal of mineral matter and sulfur compounds.

Different leaching systems involving inorganic and organic acids, hydrogen peroxide, and combined oxidative reagents were evaluated under various experimental conditions. Particular attention was devoted to a two-step treatment combining nitric acid and a H_2O_2/HNO_3 oxidative system. Structural and compositional changes in treated coal samples were analyzed using X-ray diffraction (XRD) and Fourier-transform infrared spectroscopy (FTIR).

The obtained results demonstrate that the combined two-step process achieved the highest efficiency in simultaneous ash and sulfur removal while preserving the organic coal matrix and increasing fixed carbon content. A pronounced synergistic effect between oxidative and acidic treatments was observed, resulting in substantially improved performance compared to individual treatments.

Electrochemical desulfurization using dimensionally stable anodes (DSA) was also investigated and compared with conventional graphite electrodes. The DSA system exhibited higher desulfurization efficiency, lower activation energy, and more favorable energy consumption characteristics. In addition to sulfur and mineral matter removal, the applied procedure enabled recovery of copper-containing fractions, indicating the possibility of simultaneous coal upgrading and secondary raw material recovery.

The findings indicate that integrated chemical and electrochemical approaches represent a promising strategy for upgrading low-rank coals with high mineral and sulfur contents while supporting cleaner coal utilization and resource recovery technologies.

This presentation is based on results previously published as part of the author's doctoral dissertation.

Keywords: *electrochemical; low-rank coal; environmentally; oxidative system*

Acknowledgements

This work was supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (Contract No. 451-03-33/2026-03/200023).

Investiciono i tekuće održavanje sistema za transport sirove nafte cevovodom i skladištenje kao i transport euro dizela cevovodom i skladištenje

Željko Krivačević*, Dejan Grgić, Saša Stojanović, Aleksandar Pešić

Transnafta AD, Pančevo, Srbija

https://doi.org/10.65614/uisk_yucorr.2026.27.ch3

*Zeljko.Krivacevic@transnafta.rs

Izvod

Za potrebe snabdevanja rafinerije nafte Pančevo vrši se kontinualan transport sirove nafte naftovodom počevši od 1979 godine i danas kao i skladištenje sirove nafte kako za potrebe manipulacija tako i za državne obavezne rezerve. Transport i skladištenje euro dizela vrši se na drugoj lokaciji a u cilju državnih obaveznih rezervi i za potrebe ministarstva odbrane odnosno vojske srbije. Usled dugotrajnih procesa korišćenja sistema za transport i skladištenje jedan od najvažnijih faktora sigurnog, bezbednog i pouzdanog rada sistema zahteva adekvatan pristup investicionom i tekućem održavanju sa značajnim ulaganjima.

Uvod

Odlukom Vlade Republike Srbije, 01.10.2005. godine osnovano je JP ”Transnafta”- javno preduzeće za transport nafte naftovodima i transport derivata nafte produktovodima sa sedištem u Pančevu.
Kvalitetno i pouzdano funkcionisanje cevovodnog transportnog sistema uključujući i rezervoarski prostor se može postići samo redovnim investicionim i tekućim održavanjem.
Transport sirove nafte naftovodom, vrši se od reke Dunav na granici sa Republikom Hrvatskom do Pančeva, u ukupnoj dužini od 153,4 km.
Trasa naftovoda Transnafta AD sastoji se od dve deonice :
- Deonica DN-01: Dunav – Terminal Novi Sad (dužine cca 63,4 km), prečnika Ø26“
- Deonica DN-02: Terminal Novi Sad – MS Pančevo (dužine cca 91 km), prečnika Ø18“
Pripadajuću infrastruktoru naftovoda čini:

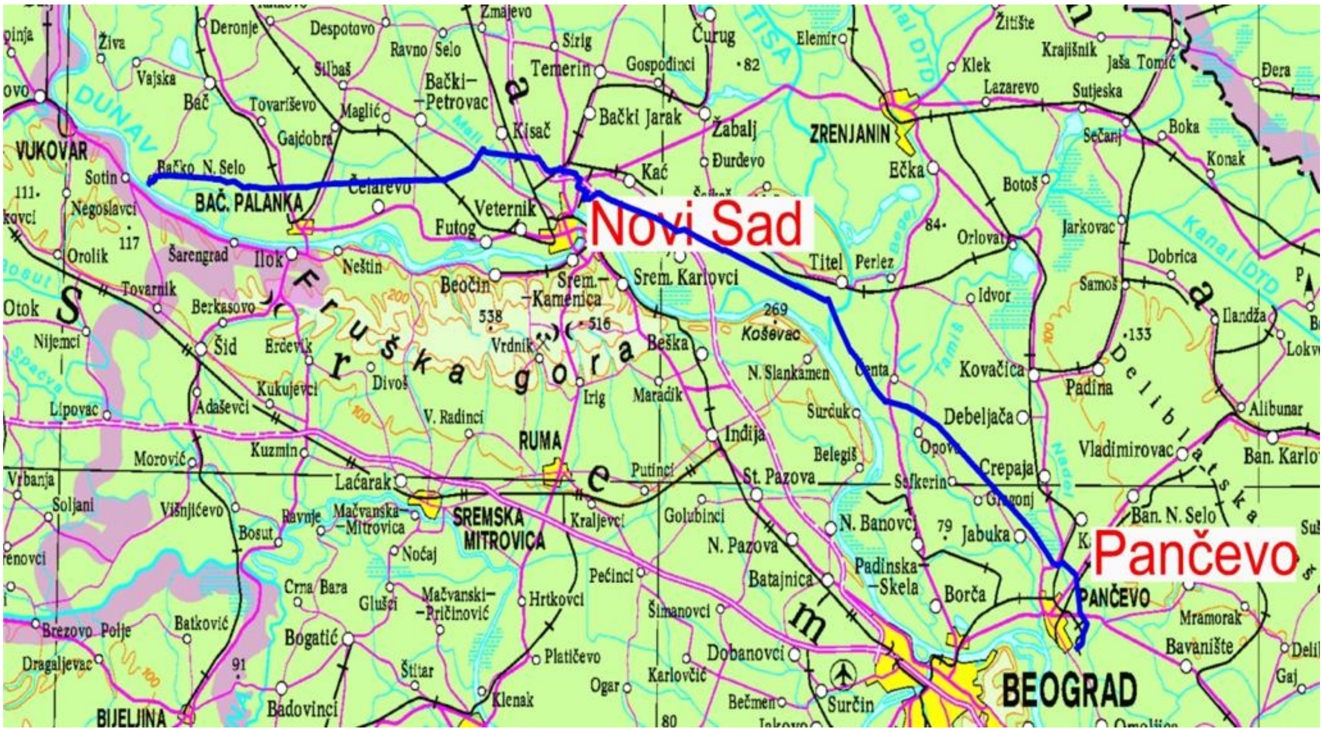
- Terminal u Novom Sadu sa pumpnom stanicom,
- rezervoarski prostor za sirovu naftu (2 x 20.000 m^3 + 4 x 10.000 m^3),
- dispečerski centar (NUS),
- merna stanica u Pančevu,
- osam blok stanica duž trase naftovoda.

Proširenje delatnosti Transnafta AD (država je vlasnik 100% akcija) dešava se u vidu skladištenja sirove nafte i derivata nafte euro dizel.
Trenutni kapaciteti:
Sirova nafta: lokacija Terminal Novi Sad 80.000 m^3
Euro dizel: Skladište Ledinci 74.000 m^3
Opredeljenost saradnje prema kratkoročnim i dugoročnim planovima sa:

- Ministarstvo rudarstva i energetike – Uprava za rezerve energenata
- Ministarstvo trgovine – Republička direkcija za robne rezerve
- Ministarstvo odbrane

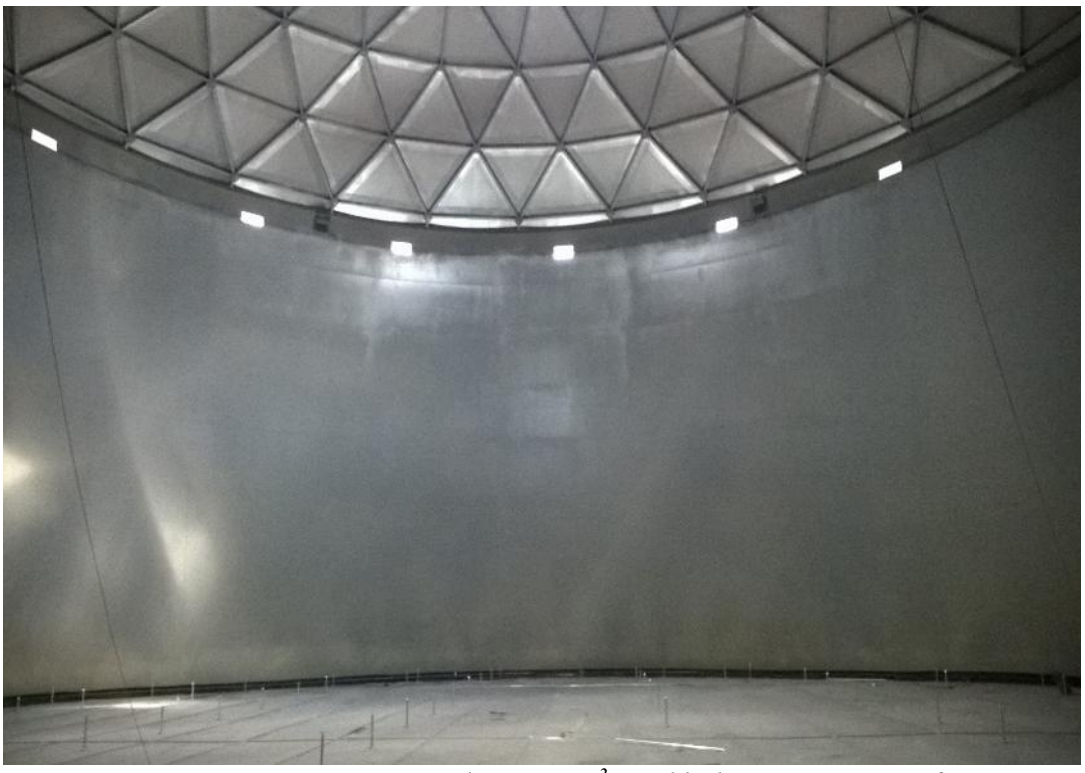
Pumpa za transport sirove nafte.

Rezervoari za skladištenje sirove nafte u betonskim tankvanama.



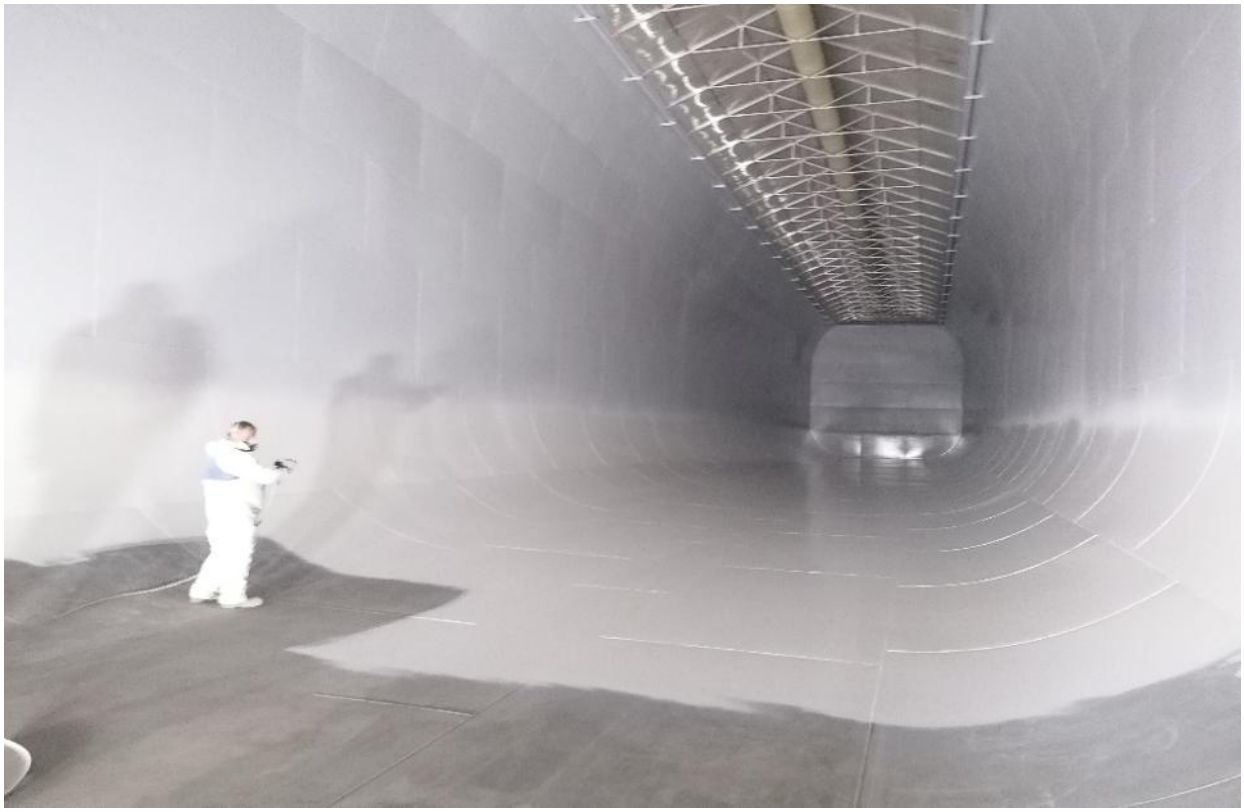
Trasa naftovoda za transport sirove nafte.

Rezervoar od 20.000 m^3 za skladištenje sirove nafte.



Unutrašnjost rezervoara od 20.000 m^3 za skladištenje sirove nafte.

Unutrašnjost rezervoara od 20.000 m^3 za skladištenje sirove nafte – ispod plivajuće membrane.



Unutrašnjost rezervoara od 12.000 m^3 za skladištenje euro dizela – u toku radova na AKZ.

Unutrašnjost rezervoara od 12.000 m^3 za skladištenje euro dizela – radovi skidanja starog čeličnog lima.

Nakon dugogodišnjeg korišćenja sistema za transport sirove nafte, skladištenje sirove nafte i sistema za transport euro dizela i skladištenje euro dizela, investiciono i tekuće održavanje čini ključan parametar za siguran i bezbedan rad a zahteva značajna konstantna ulaganja.
Deo investicionog i tekućeg održavanja odnosi se i na razne vrste ispitivanja trenutnog stanja sistema na osnovu kojih se i donose odluke u dalja ulaganja.
Neka od značajnijih ispitivanja i odluka u ulaganja na osnovu istih su i: uticaj unutrašnje korozije čeličnih cevovoda i zamena starih sa novim, ispitivanje naftovoda sa intelegentnim kracerom sa MFL metodom i sanacija na osnovu izveštaja, ispitivanje čeličnog poda rezervoara sa MFL metodom i sanacija nakon rezultata ispitivanja, ispitivanje sferičnih čeličnih krovova rezervoara sa MFL i RMS metodom i sanacija i jedan deo primene zaštite čelične konstrukcije u vidu katodne zaštite (kako čeličnog poda rezervoara tako i na istom principu katodne zaštite ukopanih čeličnih cevovoda za transport sirove nafte i transport euro dizela).

Uticaj unutrašnje korozije čeličnih cevovoda za transport derivata nafte i zamena starih sa novim

Podzemni čelični cevovodi za transport derivata nafte su dugo bili van upotrebe i bez ikakvog transporta derivata nafte, preko 25 godina (osim u dva navrata kada su izvršena hidrostatička ispitivanja sa vodom 2002. i 2008. godine) i sa delimičnim radom aktivne katodne zaštite nametnutom strujom. Za očekivati je bilo da je u ukopanim čeličnim (Č.1212) cevovodima dimenzija Ø168.3x4.5 mm, usled elektrohemijskih korozionih procesa došlo do nastanka i deponovanja intruzivnog materijala.

Unutrašnjost čeličnog cevovoda sa unutrašnjom korozijom.

Nakon preuzimanja skladišta za naftne derivate i transportnog sistema, od 2011 godine vršena su ispitivanja četiri cevovoda dužine od po 7 km u cilju otkrivanja eventualnih oštećenja i da se na osnovu rezultata ispitivanja izvrši potrebna sanacija. Dugotrajan proces *ispitivanja po deonicama od po 500m sa pritiskom vode na 50 bar, sanacija mesta otkrivenih perforacija (sečenjem delova čeličnih cevovoda i ugradnja novih komada), zatim ponovna ispitivanja nakon sanacija, završen je do 2015 godine kada je i izvršen prvi transport derivata nafte euro dizel kroz svaki od četiri cevovoda.
*Ispitivanjem hermetičnosti cevovoda vodom hidrostatičkim pritiskom ili podizanjem pritiska sa pumpom visokog pritiska, otkrilo se mnogo perforacija nastalih radom unutrašnje elektrohemijske korozije a kao rezultat ispitivanja je isticanje vode pod pritiskom na mestima perforacija.

Perforacija sa donje strane čeličnog cevovoda.

Takođe, rekonstruisan je i sistem aktivne katodne zaštite nametnutom strujom i držanjem podzemnih čeličnih cevovoda za transport derivata nafte konstatno na negativni potencijal od minus 850mV.
Nakon sedam godina redovnog korišćenja i redovnog održavanja, dolazilo je u nekoliko navrata do popuštanja čelične konstrukcije podzemnih čeličnih cevovoda usled starosti i sa delimičnim izlivanjem derivata nafte u zemljište. Sva mesta oštećenja su bila van mesta koja su prethodnih godina sanirana. Vodeći računa o zaštiti životne sredine, stanovništva (od ukupno 7 km trase, 4 km trase četiri cevovoda prolazi kroz naseljeno mesto) doneta je odluka da se od postojeća četiri cevovoda dva zamene kompletno sa novim. Tokom 2022 godine izvršeni su radovi na ugradnji dva nova čelična cevovoda ukupne dužine 14km istog spoljašnjeg prečnika Ø168.3mm i njihovo puštanje u rad.
Praktično, od 2011 godine do 2022 godine, na investiciono i tekuće održavanje 28 km podzemnih čeličnih cevovodi za transport derivata nafte uključujući i zamenu 14 km starih sa novim cevovodima, utrošeno je preko tri miliona eura.

Prethodni radovi i metode na utvrdjivanju stanja ukopanih čeličnih cevovoda

Definisanje metodologije ispiranja i hermetičnog ispitivanja ukopanih čeličnih cevovoda za transport derivata nafte, i njenim sprovodjenjem izvršilo se u cilju provere njihove funkcionalnosti u pogledu prohodnosti i hermetičnosti. Kontinualnim ispiranjem cevovoda vodom postiglo se spiranje i iznošenje svog nastalog i deponovanog materijala u njemu (korozione intruzije, zemlja, itd.), dok se ispitivanjem hermetičnosti cevovoda proverila nepropusnost cevovodne instalacije i njihove pripadajuće armature. Kako su predmetni cevovodi dugo bili van upotrebe, preko 25 godina (osim u dva navrata kada su izvršena hidrostatička ispitivanja sa vodom 2002. i 2008. godine) i sa delimičnim radom aktivne katodne zaštite nametnutom strujom, za očekivati je bilo da je u ukopanim čeličnim (Č.1212) cevovodima dimenzija Ø168.3x4.5 mm, usled elektrohemijskih korozionih procesa došlo do nastanka i deponovanja intruzivnog materijala (slika 1.). Ispitivanje hermetičnosti cevovoda i njegove pripadajuće instalacije izvršeno je metodom kontrole pritiska u cevovodu sa manometrom, kao i vizuelnom kontrolom praćenja nivoa vode u najvišoj tački ispitivanog segmenta. Ispitivanje se sprovelo sa hidrostatičkim pritiskom stuba vode u cevovodu, kao i sa pumpom za vodu visokog pritiska. Za proračune su korišćene standardne formule (na osnovu dužine trase i proteklog vremena): $s = a \times t^2 / 2$; s = dužina deonice, trase (m); t = vreme (sec); a = ubrzanje (m/s^2); brzina na kraju cevovoda: $v = v_0 + a \times t$ (m/sec); v_0 = početna brzina (m/sec) – ako voda kreće odozgo niz trasu, iz stanja mirovanja, onda je početna brzina bila nula; na kraju mesta ispuštanja vode, podizanjem fleksibilnog creva odredjivana je visina izbacivanja mlaza vode, računata je brzina vode koja izlazi: $v^2 = 2 \times g \times h$; h = visina izbacivanja mlaza vode (m); v = brzina isticanja vode (m/sec); g = gravitaciono ubrzanje 9,81 m/s^2 .
Ispitivanjem hermetičnosti cevovoda vodom hidrostatičkim pritiskom ili podizanjem pritiska sa pumpom visokog pritiska, otkrilo se mnogo perforacija nastalih radom unutrašnje elektrohemijske korozije a kao rezultat ispitivanja je isticanje vode pod pritiskom na mestima perforacija.
Ispitivanje hermetičnosti cevovoda vodom postepenim podizanjem pritiska sa pumpom visokog pritiska, istovremeno se pratilo na manometru kao i vizuelnim praćenjem indikacija pojave vode na površini zemljišta, što predstavlja izuzetno naporan rad za operatere i inžinjere.

Praćenje postepenog podizanja pritiska ukopanog čeličnog cevovoda.

Vizuelnim praćenjem indikacija eventualne pojave vode na površini zemljišta, u većini slučajeva se nije odmah pokazivalo zbog različite dubine ukopanog cevovoda i predstavljalo je pravi izazov pronaći mesto lokacije same perforacije.
Najveći izazov od svih je bilo pronaći mesto oštećenja, perforaciju cevovoda, na skoro ravno položenom cevovodu gde su se preduzimale više različitih metoda kao što je potiskivanja vode komprimovanim pritiskom vazduha radi brže pojave vode na površini zemljišta do proračuna na osnovu izmerene količine istekle vode preko vodomera na krajnoj tački ispitivane trase cevovoda.

Pronalaženje lokacije mesta perforacije ukopanog čeličnog cevovoda potiskivanjem vode sa komprimovanim pritiskom vazduha.

Većina perforacija je bila sa donje strane (radom unutrašnje elektrohemijske korozije) što je bilo i za očekivati.

Najveći broj perforacija sa donje strane na ukopanom čeličnom cevovodu za transport derivata nafte.

Trasa cevovoda bila je na delovima pod izuzetno teškim pristupom ali i ti delovi trase su ispitivani zahtevanim ispitnim pritiskom na 55bar, odnosno ispitivanje hermetičnosti cevovoda vodom postepenim podizanjem pritiska sa pumpom visokog pritiska.

Ispitivanje hermetičnosti ukopanog čeličnog cevovodu na 55 bar.

Na osnovu mnogih dokumentovanih izveštaja i procena daljeg predvidjenog „veka“ eksploatacije, doneta je odluka o zameni dela trase starih ukopanih cevovoda sa novim čeličnim cevovodima.

Zamena starih čeličnih cevovoda za transport derivata nafte sa novim

Jedna od metoda koja je takodje primenjivana u odredjivanju stanja unutrašnjosti cevovoda koji su bili pod intezivnim uticajem unutrašnje elektrohemijske korozije bila je i snimanje sa kamerom na odredjenim dužinama koje su bile pristupačne. Snimci sa kamera su samo potvrdili očekivano loše stanje unutrašnjosti cevovoda a naročito u donjoj polovini. Jedna od karakteristika koja je takodje bila od uticaja na donošenje odluke o zameni cevovoda je bila i loše izvedena pasivna antikoroziona zaštita cevovoda sa spoljašnje strane koja se poklapala u najvećoj meri i sa mestima perforacije nastalih sa unutrašnje strane cevovoda.

Loše izvedena pasivna AKZ ukopanog čeličnog cevovoda.

Zamena cevovoda izvršena je standardnom procedurom:

- kopanje, sečenje, vadjenje, postavljanje novih predizolovanih cevovoda, spajanje zavarivanjem, IBR zavarenih spojeva, izolovanje delova gde je vršeno zavarivanje, ispitivanje izolacije, ispitivanje cele trase cevovoda na hermetičnost, zatrpavanje, povezivanje na aktivan sistem katodne zaštite nametnutom strujom, merenje potencijala čeličnih cevovoda;
- izrada tehničke dokumentacije sa priloženim atestima kao i prilaganje dokumentacije o svim ispitivanjima kako od strane izvođača radova tako i od ovlašćenih sertifikovanih kuća sa važećom akreditacijom;
- izdavanje garancije na izvedene radove;
- obračun radova preko listova gradjevinskog dnevnika;
- primopredaja radova i dokumentacije;
- plaćanje.

Postavljanje novih predizolovanih čeličnih cevovoda.

Postavljanje novih predizolovanih čeličnih cevovoda – izolovanje mesta zavaravivanja.

Postavljanje novih predizolovanih čeličnih cevovoda – kroz naseljeno mesto.

Novo otpremno kracersko mesto – za potrebe čišćenja i održavanja.

Jedan tip kracera – za potrebe čišćenja i održavanja.

Aktivna katodna zaštita nametnutom strujom

Katodna zaštita od elektrohemijske korozije zasniva se na katodnoj polarizaciji metala do potencijala (minus 850 mV) pri kom se usporava proces jonizacije i prekida proces korozije. Izvor struje polarizacije je spoljni izvor jednosmerne struje. Kriterijumi katodne zaštite definišu uslove pod kojima je moguće sistemom katodne zaštite izvesti zaštitu od elektrohemijske korozije spoljašnjih ili unutrašnjih površina metalnih konstrukcija koje su položene u elektrolit. Osnovni kriterijumi katodne zaštite su električne veličine, zaštitni potencijal Ez (V), odnosno minimalna katodna polarizacija i minimalna gustina zaštitne struje. U praksi najčešće primenjivan je kriterijum minimalnog zaštitnog potencijala - Ezmin. Stacionarni potencijal čelika u prirodnim sredinama se najčešće kreće u granicama od - 0,55 V do - 0,65 V u odnosu na referentnu Cu / CuSO4 elektrodu.
Da bi se ostvarila katodna zaštita, neophodno je izvršiti polarizaciju čeličnih cevovoda najmanje za - 0,3 V ili vrednost zaštitnog potencijala u svakoj tački mora iznositi najmanje E = Ez min., odnosno E = - 0,85 V mereno između kontrolno mernog stuba i zasićene referentne Cu/CuSO4 elektrode (za anaerobne sredine u kojima bakterije redukuju sulfate do sulfida, minimalan zaštitni potencijal iznosi - 0,95 V).

Rezultati kontrolnog merenja uspostavljenog sistema katodne zaštite

Nakon polarizacije zaštićene strukture sistemom katodne zaštite izvršena je kontrola rada sistema katodne zaštite, postavljanja i povezivanja stanica za katodnu zaštitu, a izvršena merenja su u skladu sa standardom SRPS/EN 13509. Vršeno je merenje prirodnog potencijala, a nakon puštanja u rad i potencijali na svim postavljenim mernim elementima (sondama). Posle perioda polarizacije od oko 6 meseci, izvršena su kontrolna merenja.
Dobijeni su sledeći rezultati: СКЗ – 01(RADI U=13 V , I =2,2 A ,brojilo 3045 kWh); СКЗ – 02(RADI U=14 V , I =1 A , brojilo 4265 kWh); СКЗ – 03 (RADI U=30 V , I =6 A ,brojilo 6757 kWh); СКЗ – 04 (RADI U=32 V , I = 9 A ,brojilo 4284 kWh); СКЗ – 4 (RADI U= 18 V , I= 2,5 A, brojilo kWh = 2673); СКЗ – 1 (RADI U= 6 V , I= 2,2 A, brojilo kWh = 30110); СКЗ – 2 1 (RADI U= 34 V , I= 2 A, brojilo kWh = 5973); СКЗ – 3 (RADI U= 3 V , I= 0,2 A, brojilo kWh = 1911); СКЗ – 5 (RADI U= 10 V , I= 5,5 A, brojilo kWh = 481);

Napomene pre zaključka

Od momenta kada se prepozna mogućnost primene naprednih tehnika i tehnologija za potrebe kvalitetnog investicionog i tekućeg održavanja, put do realizacije i same primene je zahtevan i traži konstantnu posvećenost i strpljivost a budžet za primenu takvih naprednih tehnika i tehnologija u većini slučaja ne predstavlja problem koliko otpor ka primeni nečeg novog i nepoznatog koje zahteva dodatna učenja i usavršavanja.

Zaključak

1. Da je potrebno kao i kod svakog sistema, redovno održavanje čeličnih cevovoda čišćenjem sa kracerima, obilazak trase cevovoda, kontrola parametara rada (pritisak, temperatura), kontrola kvaliteta fluida koji se transportuje (visok sadržaj sumpora može oštetiti čelilične cevovode).
2. Da je potrebno kao i kod svakog sistema, redovno održavanje sistema katodne zaštite prema upustvu isporučioca katodne zaštite i prema upustvu o održavanju i ispitivanjima sistema katodne zaštite koje je predložio izvodjač radova.
3. Da je potrebno redovno ispitivanje, pregled i merenje katodne zaštite;

Praksa je pokazala da je tokom veka eksploatacije čeličnih cevovoda za transport sirove nafte, derivate nafte više od 80 % oštećenja nastaje na donjoj strani a ispitivanja sa intelegentnim kracerom je dosta skupo (1500 $/km) i radi se na svakih 5 godina (iskustvena praksa). Zato je potrebno da katodna funkcioniše besprekorno kao i sistem redovnog održavanja.

OxyRePair Project – A Story With Industrial Potential

Vladimir V. Panić[1,2,*]

[1]*University of Belgrade, Institute of Chemistry, Technology and Metallurgy, Belgrade, Serbia*

[2]*State University of Novi Pazar, Novi Pazar, Serbia*

[*]*panic@ihtm.bg.ac.rs*

Abstract

The presentation reports on achievements reached on a research project, OxyRePair - Renewal of the Waste Oxygen-Evolving anodes from Hydrometallurgy and their improved Activity for Hydrogen Economy, Wastewater and Soil Remediation, realized within the Green Program of Cooperation between Science and Industry of the Science Fund of the Republic of Serbia, during 2023–2025. Main deliverables related to novel oxygen-evolving anode production/renewal procedure are presented. Innovative procedure succeeded in fabricating anode coatings of structurally-ordered oxide coatings, reaching in less-expensive oxides by applying spray pyrolysis/hydrothermal synthesis and modified aerosol-brushing application. The extended anode service lives in water electrolysis from an acid solution is registered. An optimized, easy-to-use methodology for an industrial-friendly procedure for the reparation of waste anodes of improved service characteristics is demonstrated. The procedure should be equally valid for the production of new anodes for the environmentally-friendly processes of wastewater soil treatments, cathodic protection of in-soil, sea water and concrete metallic constructions, as well as the anodes of water electrolyzers for hydrogen fuel production from renewable energy sources. The results directly impact the reduction of industrial wastes, sustainable energy consumption and production, as well as production costs in the food industry, metallurgy and corrosion protection, with simultaneous self-sustainable progress toward clean technologies in heavy industry.

Keywords*: oxygen-evolving anodes; hydrogen economy; waste recycling; sustainable technologies*

Acknowledgments

Authors wish to acknowledge the support of the Science Fund of the Republic of Serbia, PROJECT NUMBER 6666, Renewal of the Waste Oxygen-Evolving anodes from Hydrometallurgy and their improved Activity for Hydrogen Economy, Wastewater and Soil Remediation - OxyRePair.

POSTER PRESENTATIONS
POSTERSKA SAOPŠTENJA

Photostability of Common Organic UV Filters under Different Radiation Sources

Nemanja Banić[1,*], Ivana Basarić[1], Teodora Vidović[1], Dina Tenji[2]

[1]*University of Novi Sad, Faculty of Sciences, Department of Chemistry, Biochemistry and Environmental Protection, Trg Dositeja Obradovića 3, 21000 Novi Sad, Serbia*

[2]*University of Novi Sad, Faculty of Sciences, Department of Biology and Ecology, Trg Dositeja Obradovića 2, 21000 Novi Sad, Serbia*

[*]*nemanja.banic@dh.uns.ac.rs*

Abstract

Organic UV filters are widely used in sunscreens, personal care products, and polymer-based materials. Despite their regulatory approval for use, their frequent detection in the environment and possible adverse health effects have become a growing concern. This study examines the photostability of four commonly used organic UV filters, namely avobenzone, oxybenzone, octisalate, and octocrylene, under three different radiation sources: halogen lamps (simulated solar radiation (SSR)), high-pressure mercury lamps (ultraviolet radiation (UV)), and germicidal lamps (ultraviolet radiation type C (UVC)) in a 50:50 (v/v) acetonitrile–ultrapure water mixture. Initial spectrophotometric analyses revealed differential photolysis: avobenzone remained largely stable under SSR for 360 min, whereas UV and UVC radiation induced substantial degradation (88.12% and 100%, respectively). Oxybenzone showed negligible photodegradation, while octisalate and octocrylene underwent limited photolysis, predominantly under UVC (14.93% and 6.93%, respectively). Variations in pH mirrored photodegradation efficiency. To achieve precise quantification and identify photoproducts, HPLC analyses were performed using optimized mobile phases: avobenzone (80% ACN:20% 0.1% H_3PO_4; t_r = 8.59 min), octisalate (90% ACN:10% 0.1% H_3PO_4; t_r = 5.58 min) oxybenzone (65% ACN:35% 0.1% H_3PO_4; t_r = 4.97 min), and octocrylene (85% ACN:15% 0.1% H_3PO_4; t_r = 5.79 min). HPLC confirmed the trends observed by spectrophotometric analysis and enabled precise determination of photodegradation efficiencies, which was particularly important due to the overlap of absorption maxima of intermediates and the parent compounds in spectrophotometric measurements. The resulting efficiencies were: avobenzone (SSR 39.88%, UV 92.84%, UVC 99.75%), octisalate (SSR 0%, UV 2.22%, UVC 24.76%), oxybenzone (0% under all conditions), and octocrylene (SSR 0%, UV 10.88%, UVC 12.96%). Chromatograms revealed multiple polar intermediates for compounds undergoing photolysis. These findings emphasize the markedly different photostabilities of common UV filters and highlight the necessity for further research into the chemical structure and ecotoxicological effects of photoproducts, which is essential for informed environmental risk assessment and the development of sunscreen formulation strategies.

Keywords: *UV filters; Photostability; Environmental pollution; High-performance liquid chromatography*

Acknowledgements

The authors acknowledge the financial support of the Provincial Secretariat for Higher Education, Scientific and Research Activity of Vojvodina, Republic of Serbia (grant no. 003785794 2025 09418 003 000 000 001 04 002).

Calcination temperature effects on the efficiency of fluorescein removal and hydrogen production over sol–gel TiO_2 prepared at different acid concentrations under simulated solar radiation

Teodora Vidović[1], Ivana Basarić[1], Dina Tenji[2], Nemanja Banić[1,*]

[1]*University of Novi Sad, Faculty of Sciences, Department of Chemistry, Biochemistry and Environmental Protection, Trg Dositeja Obradovića 3, 21000 Novi Sad, Serbia*

[2]*University of Novi Sad, Faculty of Sciences, Department of Biology and Ecology, Trg Dositeja Obradovića 2, 21000 Novi Sad, Serbia*

[*]*nemanja.banic@dh.uns.ac.rs*

Abstract

The photodegradation of organic dyes combined with hydrogen production under solar radiation represents a promising approach as a solution to both environmental pollution and energy-related challenges. In particular, photocatalytic hydrogen evolution under solar radiation has attracted significant attention as a sustainable alternative to fossil fuels. Photocatalysis is widely recognized as a green and cost-effective technology for environmental remediation and clean energy production. In this study, TiO_2 nanoparticles were synthesized via a sol–gel method using titanium butoxide as a precursor and HNO_3 as a solvent. Two different acid concentrations were used (4.78 mmol/dm^3 and 0.287 mol/dm^3 HNO_3), while the calcination temperature was varied between 500 and 800 °C. The photocatalytic activity of the synthesized materials was evaluated through fluorescein removal and photocatalytic hydrogen production under simulated solar radiation. The results demonstrate that both the structural and photocatalytic properties of TiO_2 strongly depends on the acid concentration and calcination temperature. TiO_2 synthesized using 0.287 mol/dm^3 HNO_3 exhibited a low adsorption capacity at 500 °C (6.81%), while achieving a high fluorescein removal efficiency of 99.58% after 60 min of irradiation. No significant adsorption was observed at higher calcination temperatures for this sample. In contrast, TiO_2 prepared using 4.78 mmol/dm^3 HNO_3 showed near-complete fluorescein removal after 60 min at 500 and 600 °C (97.84% and 98.61%, respectively), but with significantly higher adsorption contributions (62.67% and 14.4%, respectively). The highest hydrogen production rate of 11.37 μmol/g·h was obtained for TiO_2 synthesized with 0.287 mol/dm³ HNO_3 and calcined at 500 °C, while the corresponding value for the second sample was 6.71 μmol/g·h at 600 °C. Overall, both photocatalytic degradation efficiency and hydrogen production rates decreased with increasing calcination temperature for both types of TiO_2. This trend can be attributed to phase transformation from anatase to rutile with increasing temperature, as reported in the literature.

Keywords: *Heterogeneous photocatalysis; Titanium oxide; Sol–gel method; Fluorescein; Hydrogen generation; Simulated solar radiation*

Acknowledgements

This study is supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (grants no. 451-03-33/2026-03/200125 and 451-03-34/2026-03/200125). The authors express their gratitude to Srbijagas for donating the gas chromatograph, which enabled the realization of this research.

Contamination and ecological risk assessment of potentially toxic elements in recultivated fly ash disposal sites

Dragana Pavlović*, Marija Matić, Olga Kostić, Natalija Radulović, Dimitrije Sekulić, Miroslava Mitrović, Pavle Pavlović

[1] *Department of Ecology, Institute for Biological Research "Siniša Stanković"-National Institute of the Republic of Serbia, University of Belgrade, Bulevar despota Stefana 142, 11000 Belgrade, Serbia*

dragana.pavlovic@ibiss.bg.ac.rs

Abstract

Coal combustion in thermal power plants is a major anthropogenic source of potentially toxic elements (PTEs), and long-term fly ash disposal can lead to their accumulation in the environment and increased ecological risk. This study aimed to determine the content of PTEs in recultivated ash from the Nikola Tesla B thermal power plant disposal site (Obrenovac, Serbia) and to assess the degree of geochemical enrichment, contamination, and potential ecological risk using geochemical indices. Samples were collected from approximately 20-year-old recultivated lagoons at a depth of 20-30 cm, along transects from the periphery toward the center of the site in all main directions. After microwave-assisted digestion in aqua regia, concentrations of Al, As, B, Ba, Co, Cr, Cu, Fe, Mn, Ni, Pb, Sr, Tl, and Zn were determined using ICP-OES. To evaluate geochemical enrichment, contamination and potential ecological risk, the enrichment factor (EF), contamination factor (Cf), degree of contamination (Cdeg), ecological risk factor (Er^i), and potential ecological risk index (RI) were calculated. Upper Continental Crust (UCC) values according to Wedepohl (1995) were used as the geochemical background, and Al was used as the reference element for EF due to its lithogenic origin and low mobility. Average concentrations of As, Cr, Ni, and B exceeded the maximum allowable values established by national regulations. Enrichment factor values indicated minimal enrichment (<2) for Ba, Co, Fe, Mn, Pb, Sr, and Zn; significant enrichment (5-20) for B, Cr, Cu, Ni, and Tl; and very high enrichment for As. The contamination factor (Cf) indicated low contamination (<1) for Ba and Sr, moderate (1-3) for Co, Fe, Mn, Pb, and Zn, considerable (3-6) for Cr and Cu, and very high (>6) for As, B, Ni, and Tl. The overall degree of contamination (Cdeg) indicated a very high level of contamination (>32). Individual ecological risk factor (Er^i) values indicated low risk for Cr, Cu, Co, Mn, Ni, Pb, and Zn, while As was the dominant contributor to overall ecological risk. The total potential ecological risk index (RI) indicated a high ecological risk level (160-320). The results show that recultivated ash disposal sites, even after approximately 20 years of stabilization, remain significant reservoirs of PTEs in the surface layer of fly ash. The high enrichment of As and its dominant contribution to overall risk highlight the need for continuous monitoring and assessment of PTEs mobility in these technogenic systems. These findings improve understanding of their long-term geochemical stability and may serve as a basis for enhancing ash disposal site management and remediation strategies.

Keywords: *Fly ash disposal sites; potentially toxic elements; geochemical indices; ecological risk assessment; arsenic contamination*

Acknowledgements:

This work was supported by the Ministry of Science, Technological Development and Innovation of Serbia, grant no. 451-03-33/2026-03/200007.

Bioaccumulation and translocation of potentially toxic elements in *Echium vulgare* growing on a coal ash lagoon and implications for phytostabilization

Marija Matić*, Dragana Pavlović, Ksenija Jakovljević, Olga Kostić, Natalija Radulović, Miroslava Mitrović, Pavle Pavlović

Department of Ecology, Institute for Biological Research „Siniša Stanković" – National Institute of Republic of Serbia, University of Belgrade, Bulevar Despota Stefana 142, 11108 Belgrade, Serbia

**marija.pavlovic@ibiss.bg.ac.rs*

Abstract

The growing energy demands of humanity have led to increased coal combustion as a key resource for electricity production. Among the largest producers of coal-based electricity are China (395 Mt), the USA (118 Mt), and India (105 Mt), while approximately 52 Mt are produced within the European Union. In Serbia, electricity is predominantly generated by the public company Elektroprivreda Srbije (EPS), where low-calorific coal -lignite is used as the main fuel, resulting in the production of about 5.5 million tons of ash annually. The disposal of ash, slag, and other combustion products is carried out at ash disposal sites, which are often located near populated areas and represent a significant source of air, water, and soil pollution. These materials are most commonly disposed of in wet lagoons or directly into lakes after dilution, leading to the accumulation of potentially toxic elements (PTEs) in soil and groundwater, while fine ash particles are easily dispersed into the surrounding environment. Therefore, establishing vegetation cover on such degraded areas is crucial for their physical and chemical stabilisation. Plants able to survive in these extreme conditions must be adapted to high concentrations of PTEs, alkaline substrate reaction, nutrient and organic matter deficiency, low water retention, drought, high temperatures, intense UV radiation, wind erosion, unstable substrate, salinity, oxidative stress, and impaired root development. Despite these challenges, the establishment of vegetation cover is possible, with herbaceous species proving particularly successful. To investigate the adaptations of spontaneously colonised herbaceous species, research was conducted in 2025 on an ash lagoon covering 200 ha within TENT B, Obrenovac, Serbia, which was recultivated in 2008. The content of PTEs was analysed in ash and in the plant species Echium vulgare from the family Boraginaceae, with composite samples formed for ash, taken from a depth of 20 cm below each individual plant, and for plant material (leaves and roots of the studied species). Biological factors – bioaccumulation factor (BAF), bioconcentration factor (BCF), and translocation factor (TF) were determined to assess its potential for tolerance, exclusion, and phytostabilisation of PTEs. Chemical analysis was performed using the ICP-OES technique, while biological factors were calculated according to standard literature formulas. The results showed toxic concentrations of several elements (B, Co, Cr, Li, Mo, Se) in plant tissues, while BAF and BCF values were <1 for most elements, indicating limited phytoremediation capacity. However, TF values >1 for elements such as B, Ba, Co, Cr, Li, Mn, Ni, and Sr indicate pronounced translocation from roots to aboveground parts. The species is characterised by an erect, branched, and densely hairy stem reaching 30–100 cm in height, and a strong taproot system that enables efficient uptake of water and nutrients from deeper substrate layers, contributing to its high tolerance to dry and degraded conditions.

The results indicate that although Echium vulgare demonstrates high tolerance to degraded ash substrate, its phytoremediation potential is limited due to low BAF and BCF values (<1) for most elements, suggesting poor suitability for phytoextraction purposes. However, the observed TF values (>1) for several elements, including Cr and Ni, indicate efficient translocation from roots to aboveground tissues, which may increase the risk of element entry into higher trophic levels through

herbivory. Consequently, the species cannot be considered a true phytoexcluder, but rather a tolerant coloniser of technogenic substrates with limited stabilising efficiency. These findings highlight the importance of further investigating species-specific mechanisms of element uptake and internal transport, as well as their implications for long-term ecological risk assessment and management of ash disposal sites.

Keywords: *ash disposal sites; Echium vulgare; potentially toxic elements; biological factors; phytostabilization*

Acknowledgment:

This work was supported by the Ministry of Education, Science, and Technological Development of the Republic of Serbia, grant no. 451-03-33/2026-03/200007

Nitric Acid Leaching of Coal with Acid Recirculation: Process Efficiency and Environmental Benefits

Katarina Pantović Spajić[1,*], Nikola Vuković[1], Katarina Radosavljević[2], Dimitrije Anđić[1], Ivana Mikavica[1], Milica Mišić[1], Branislav Marković[1]

[1]*Institute for Technology of Nuclear and Other Mineral Raw Materials, 11000 Belgrade, Serbia*

[2]*Faculty of Mining and Geology, University of Belgrade, 11000 Belgrade, Serbia*

[*]*k.pantovic@itnms.ac.rs*

Abstract

Coal combustion releases hazardous substances, particularly sulfur compounds, and generates ash, both of which have adverse effects on the environment and human health. For this reason, coal pretreatment is applied to reduce these components before utilisation.
In this study, nitric acid leaching was investigated as a method for coal purification, using subbituminous coal from the Bogovina Basin (Eastern Serbia).
The primary objective was to evaluate the reuse of nitric acid through recirculation. Following each leaching step, the spent acid was returned to the system and applied to fresh coal samples. In each cycle, the acid concentration was adjusted to 15% by adding concentrated nitric acid. The process was monitored over six consecutive cycles by measuring ash and sulfur content, as well as concentrations of metals (As, Cd, Cr, Co, Cu, Mo, Ni, Pb, and Zn) in the filtrates.
The results showed that the degrees of demineralization and desulfurization remained nearly constant across all cycles. Meanwhile, metal concentrations in the leachates increased with the number of cycles, indicating accumulation in the solution.
These findings demonstrate that acid recirculation reduces reagent consumption, improves process economics, and lowers environmental impact, while simultaneously reducing ash and sulfur content and generating a metal-enriched solution as a potential secondary resource.

Keywords: *ash; coal; environment; nitric acid; recirculation; sulfur*

Acknowledgements

This work was supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (Contract No. 451-03-33/2026-03/200023).

Monitoring of Surface Water Quality in the Bor Area: Results of the Initial Phase of a Year-Long Study Starting From October 2025

Monitoring kvaliteta površinskih voda na području Bora: Rezultati početne faze jednogodišnjeg istraživanja sa početkom u oktobru 2025. godine

Stefan Đorđievski*, Ana Petrović, Miloš Đukić, Dragana Adamović, Bojan Radović, Tamara Urošević, Renata Kovačević

Mining and Metallurgy Institute Bor, Alberta Ajnštajna 1, Bor, Serbia

**stefan.djordjievski@irmbor.co.rs*

Abstract

The monitoring program in the City of Bor, which commenced in October 2025, is designed to span a full year to identify seasonal variations and provide a comprehensive assessment of the ecological status of local watercourses. The study is based on monitoring 15 sampling locations covering the catchments of the Kriveljska, Borska, Bela, and Brestovačka rivers, as well as Lake Bor and the Crni Timok river. The methodology involves weekly sampling and analysis of a wide range of physico-chemical, chemical, and microbiological parameters, including heavy metals (Cu, Fe, Mn, Zn, As, Cd, Pb, Ni, Cr) and priority hazardous substances, in accordance with the regulations of the Republic of Serbia. General results indicate critically low water quality in rivers directly impacted by mining and metallurgical activities, where the Kriveljska and Borska rivers consistently fall into Class V, representing poor ecological status. The primary causes are extremely high concentrations of sulfates, manganese, and ammonia, with occasional occurrences of extremely high suspended and settleable solids. In contrast, Lake Bor maintains a good ecological status (Class II), while other watercourses, such as the Brestovačka river downstream from the spa, show significant anthropogenic impact through microbiological pollution of fecal origin. These findings serve as a baseline for defining remediation measures and further ecological risk assessment in the region.

Keywords: *monitoring; surface water; Bor; water quality; heavy metals; classification*

Izvod

Program monitoringa u gradu Boru, započet u oktobru 2025. godine, koncipiran je da traje punih godinu dana kako bi se identifikovale sezonske varijacije i dobio sveobuhvatan uvid u ekološki status lokalnih vodotokova. Studija se zasniva na monitoringu 15 mernih mesta koja obuhvataju slivove Kriveljske, Borske, Bele i Brestovačke reke, kao i Borsko jezero i reku Crni Timok. Metodologija obuhvata nedeljno uzorkovanje i analizu širokog spektra fizičko-hemijskih, hemijskih i mikrobioloških parametara, uključujući teške metale (Cu, Fe, Mn, Zn, As, Cd, Pb, Ni, Cr) i prioritetne hazardne supstance, a sve u skladu sa propisima Republike Srbije. Opšti rezultati ukazuju na kritično nizak kvalitet vode u rečnim tokovima koji su pod direktnim uticajem rudarskih i metalurških aktivnosti, pri čemu se Kriveljska i Borska reka u kontinuitetu svrstavaju u V klasu, što predstavlja loš ekološki status. Glavni uzročnici su ekstremno visoke koncentracije sulfata, mangana i amonijaka, uz povremenu pojavu ekstremno visokih vrednosti suspendovanih i taložnih materija. Nasuprot tome, Borsko jezero zadržava dobar ekološki status (II klasa), dok ostali vodotokovi, kao što je Brestovačka reka nizvodno od banje, pokazuju značajan antropogeni uticaj kroz mikrobiološko zagađenje fekalnog porekla. Ovi nalazi služe kao polazna osnova za definisanje mera sanacije i dalju procenu ekološkog rizika u regionu.

Ključne reči: *monitoring; površinske vode; Bor; kvalitet vode; teški metali; klasifikacija*

Combined Process for Copper Leaching from Flotation Tailings

Kombinovani postupak luženja bakra iz flotacijske jalovine

Vanja Trifunović*, Ljiljana Avramović, Milutin Stojadinović, Ivana Mikić, Sanela Vasiljević, Dragana Božić, Marija Jonović

Mining and Metallurgy Institute Bor, Albert Ajnštajn 1, 19210 Bor, SERBIA

**vanja.trifunovic@irmbor.co.rs*

Abstract

This paper presents experimental results of the copper leaching process from composite samples of flotation tailings taken from the Old Flotation Tailings Dump (OFTD) of the Mining and Smelting Complex Bor (now Serbia ZiJin Copper doo) in eastern Serbia. OFTD is a typical example of a source of contamination due to the drainage process with acidic mine waters, with an average copper content of 0.23%. The process of acid leaching of copper from flotation tailings at atmospheric pressure achieved a copper leaching rate of 78% at ambient temperature. An additional leaching of copper at high pressure (OHPL) and high temperature in an autoclave in the presence of an oxidant achieved an additional leaching rate of 15% Cu. By applying a combined copper leaching process from flotation tailings, which includes a two-stage copper leaching: in the first stage - acid leaching at atmospheric pressure, and additionally in the second stage - leaching of the obtained solid residue, at high pressure and high temperature, a total copper leaching rate of 93% was achieved. The significance of the study has a twofold contribution - defining the optimal process for the copper recovery from flotation tailings as a significant potential secondary raw material, and on the other hand, solving the serious environmental problem that OFTD represents as a mining waste.

Keywords: *flotation tailings; leaching process; copper*

Izvod

U ovom radu su predstavljeni eksperimentalni rezultati procesa luženja bakra iz kompozitnih uzoraka flotacijske jalovine uzete sa Starog flotacijskog jalovišta (SFJ) Rudarsko-topioničarskog kompleksa Bor (sada Serbia ZiJin Copper doo) u istočnoj Srbiji. SFJ je tipičan primer izvora kontaminacije usled procesa drenaže kiselih rudničkih voda, sa prosečnim sadržajem bakra od 0,23%. Procesom kiselinskog luženja bakra iz flotacijske jalovine na atmosferskom pritisku, postignut je stepen izluženja bakra od 78%, na ambijetalnoj temperaturi. Dopunskim izluženjem bakra na povišenom pritisku i povišenoj temperaturi (OHPL), u autoklavu uz prisustvo oksidansa, postignut je dodatni stepen izluženja od 15% Cu. Primenom kombinovanog procesa luženja bakra iz flotacijske jalovine koji uključuje dvostepeno luženje bakra: u prvom stepenu - kiselinsko luženje na atmosferskom pritisku, i dodatno u drugom stepenu - luženje nastalog čvrstog ostatka, na povišenom pritisku i povišenoj temperaturi, postignut je ukupni stepen izluženja bakra od 93%. Značaj ispitivanja ima dvostruki doprinos – definisanje optimalnog postupka za izdvajanje bakra iz flotacijske jalovine kao značajne potencijalne sekundarne sirovine, a sa druge strane rešavanje ozbiljnog ekološkog problema koji predstavlja SFJ kao rudarski otpad.

Ključne reči: *flotacijska jalovina; proces luženja; bakar*

Core-Shell Oxide Materials as Electrocatalysts for the Oxygen Evolution Reaction

Katarina Đ. Božić[1,*], Marijana R. Pantović Pavlović[1], Marija D. Mihailović[1], Maja R. Babić[2], Vladimir V. Panić[1,3], Miroslav M. Pavlović[1]

[1]*University of Belgrade, Institute of Chemistry, Technology and Metallurgy - National Institute of the Republic of Serbia, Department of Electrochemistry, Belgrade, Serbia*

[2]*University of Belgrade, Innovation Center of Faculty of Technology and Metallurgy, Belgrade, Serbia*

[3]*State University of Novi Pazar, Novi Pazar, Serbia*

[*]*katarina.bozic@ihtm.bg.ac.rs*

Abstract

The development of efficient and durable electrocatalysts is essential for advancing sustainable energy technologies, particularly those related to hydrogen production and energy storage systems. A major challenge in these applications is the improvement of catalytic activity while reducing the share of scarce and expensive noble metals.

In this study, advanced composite catalytic materials were designed through a combination of scalable synthesis approaches and post-synthesis modification strategies. Functional oxide-based supports were engineered to provide structural stability and favorable interactions with catalytically active phases. The resulting composite materials were systematically tailored to optimize their physicochemical and electrochemical properties.

The catalytic performance of the synthesized materials was evaluated under conditions relevant to energy conversion processes. Electrochemical characterization revealed that the interaction between support materials and active components strongly influences charge transfer, interfacial processes, and overall catalytic efficiency. The choice, structural and compositional modifications of valve metal oxides were found to significantly affect the activity and stability of the noble metal oxide catalysts.

The obtained results provide insight into the design principles of high-performance catalytic systems, especially for oxygen evolution reaction with reduced noble metal content and contribute to the development of cost-effective materials for sustainable energy technologies.

Keywords: *electrocatalysis; composite materials; sustainable energy; electrochemical characterization*

Acknowledgments

Authors wish to acknowledge the support of the Science Fund of the Republic of Serbia, PROJECT NUMBER 6666, Renewal of the Waste Oxygen-Evolving anodes from Hydrometallurgy and their improved Activity for Hydrogen Economy, Wastewater and Soil Remediation - OxyRePair.

Electrochemical Study of Functionalized Titanium Surfaces for Biomedical Applications

Katarina Đ. Božić[1,*], Marijana R. Pantović Pavlović[1], Miroslav M. Pavlović[1], Vladimir V. Panić[1,2], Đorđe N. Veljović[3]

[1]*University of Belgrade, Institute of Chemistry, Technology and Metallurgy - National Institute of the Republic of Serbia, Department of Electrochemistry, Belgrade, Serbia*

[2]*State University of Novi Pazar, Novi Pazar, Serbia*

[3]*University of Belgrade, Faculty of Technology and Metallurgy, Belgrade, Serbia*

[*]*katarina.bozic@ihtm.bg.ac.rs*

Abstract

Advanced surface modifications of metallic biomaterials are increasingly employed to improve their long-term performance in physiological environments. However, the high corrosion resistance of these materials often limits the applicability of conventional electrochemical evaluation methods, as the measured response is frequently governed by changes occurring within surface layers rather than by substrate degradation itself, particularly for titanium substrates.

This study investigates the electrochemical behavior and stability of multifunctional bioactive coatings under simulated physiological conditions. Electrochemical impedance spectroscopy was used to monitor changes in resistance and capacitance associated with different coating regions and degradation stages. Controlled periodic potentiostatic polarization was applied to induce gradual degradation and assess the changes in the coatings under increasingly severe conditions.

The results demonstrate that electrochemical parameters are sensitive to structural and physicochemical transformations occurring within the coatings, including electrolyte penetration, interfacial modifications, and evolution of passive surface layers. Surface treatment was shown to significantly enhance corrosion protection, while the incorporation of bioactive components influenced the compactness and barrier properties of the coating system. The degradation process altered the morphology and electrochemical response of the outer layers, whereas internal regions exhibited increased stability under certain conditions.

Overall, the proposed methodology provides a comprehensive framework for evaluating the long-term stability and protective performance of advanced coating systems intended for biomedical applications. The findings contribute to a deeper understanding of electrochemical processes governing material behavior in physiological environments.

Keywords: *electrochemical impedance spectroscopy; bioactive coatings; corrosion resistance; surface modification*

Real-Time Monitoring Systems of Seismic Tremors Caused by Mining in the Function of Protecting Building Structures

Real-time sistemi monitoringa seizmičkih potresa izazvanih miniranjem u funkciji zaštite građevinskih struktura

Radoje Pantović*

University of Belgrade, Technical faculty in Bor, Bor, Serbia

**pan@tfbor.bg.ac.rs*

Abstract

This paper presents the characteristics and possibilities of real-time monitoring of seismic waves caused by blasting in surface mines and quarries. The system enables continuous (24/7) monitoring of: parameters of seismic tremors (velocity, acceleration, displacement, frequency spectrum of vibrations), air shock waves, reaction of cracks under the influence of seismic tremors and climatic factors and climatic parameters (air temperature and humidity).

Appropriate sensors that are independent and connected to the main server and to each other via a wireless network can be installed at a larger number of measurement points. Communication between the acquisition units at the measuring points and the main server of the central station, under the condition of optical visibility, is carried out using wireless connection equipment and appropriate software for communication and data processing and is realized continuously in real time. The entire system is time-synchronized via GPS.

Real-Time Data Streamer receives data in real time from all system sensors and allows the user to analyze and record data in real time from any computer connected to the Internet / Intranet. The user is enabled to display data in real time, set triggers, set scheduled recordings, display FFT of some selected channels in real time. Analysis and subsequent processing of data obtained from system units for permanent structural monitoring or ambient vibration measurement is performed using Observer Data Analysis Suite software. This software provides a wide range of powerful signal analysis tools that help engineers understand the behavior of building structures when seismic waves pass through their foundations.

The speed of oscillation of soil particles, during the passage of a seismic wave generated by blasting, is the most suitable parameter, which can be used to best evaluate the seismic effect of blasting on residential and construction objects. Tremors protection comes down to limiting the speed of ground oscillation, which causes damage to objects. In addition to the speed of oscillation, the occurrence of damage to objects due to seismic tremors during blasting is affected by the frequency spectrum of seismic tremors and the possibility of resonance.

Izvod

U ovom radu prikazane su karakteristike i mogućnosti real-time monitoringa seizmičkih talasa izazavanih miniranjima na površinskim kopovima i kamenolomima. Sistem omogućava kontinualno (24/7) praćenje: parametara seizmičkih potresa (brzina, ubrzanje, pomeranje, frekventni spektar vibracija), vazdušnih udarnih talasa, reakcija pukotina pod uticajem seizmičkih potresa i klimatskih faktora i klimatskih parametara (temperature i vlažnosti vazduha).

Na većem broju mernih mesta mogu se instalirati odgovarajući senzori koji su nezavisni i povezani sa glavnim serverom i međusobno putem bežične mreže. Komunikacija između akvizicionih jedinica na mernim mestima i glavnog servera centralne stanice, pod uslovom optičke vidljivosti, vrši se pomoću opreme za bežičnu vezu i odgovarajućeg softvera za komunikaciju i obradu podataka i ostvaruje se kontinuirano u realnom vremenu. Ceo sistem vremenski je sinhronizovan putem GPS-a.

Real-Time Data Streamer vrši prijem podataka u realnom vremenu sa svih senzora sistema i omogućavanje korisniku da analizira i snima podatke u realnom vremenu sa bilo kog računara vezanog na Internet / Intranet. Korisniku je omogućeno prikazivanje podataka u realnom vremenu, postavljanje trigera, postavljanje zakazanih snimaka, prikazivanje FFT nekih odabranih kanala u realnom vremenu. Analiza i naknadna obrada podataka dobijenih sa sistemskih jedinica za permanentno strukturno praćenje ili ambijentalno merenje vibracija vrši se pomoću softvera Observer Data Analisis Suite. Ovaj softver pruža širok spektar moćnih alata za analizu signala koji pomažu inženjerima da razumeju ponašanje građevinskih struktura pri prolasku seizmičkih talasa kroz njihove temelje.

Brzina oscilovanja čestica tla, pri prolasku seizmičkog talasa generisanog miniranjem, predstavlja najpogodniji parametar, kojim se najbolje može oceniti seizmičko dejstvo miniranja na stambene i građevinske objekte. Zaštita od potresa svodi se na ograničavanje brzine oscilovanja tla, pri kojoj je pojava oštećenja na objektim Pored brzine oscilovanja, na pojavu oštećenja objekata, usled seizmičkih potresa pri miniranju, utiču frekventni spektar seizmičkih potresa i mogućnost pojave rezonance.

Sodium Germanate-Loaded Amorphous Calcium Phosphate/Chitosan Oligolactate Coatings on Titanium: Structural Characterization and Interfacial Analysis

Marijana R. Pantović Pavlović[1,*], Katarina Đ. Božić[1], Miloš M. Lazarević[2], Nenad L. Ignjatović[3], Miroslav M. Pavlović[1]

[1]*University of Belgrade, Institute of Chemistry, Technology and Metallurgy - National Institute of the Republic of Serbia, Department of Electrochemistry, Belgrade, Serbia*

[2]*University of Belgrade, School of Dental Medicine*

[3]*Institute of Technical Science of the Serbian Academy of Sciences and Arts, Belgrade, Serbia*

[*]*m.pantovic@ihtm.bg.ac.rs*

Abstract

Titanium-based implant materials require surface modifications capable of improving bioactivity while enabling multifunctional performance. Sodium germanate-loaded amorphous calcium phosphate/chitosan oligolactate (ACP/ChOL/ Na_2GeO_3) coatings were developed on titanium substrates and structurally characterized using FTIR spectroscopy, SEM and EDS analysis. FTIR results confirmed successful incorporation of Na_2GeO_3 into the ACP/ChOL matrix through systematic spectral modifications, including broadening and shifting of the O–H/N–H region, enhancement of the ~1637 cm^{-1} band, development of a shoulder at ~1123–1114 cm^{-1}, and the appearance of characteristic germanate-related shoulders in the 850–650 cm^{-1} region assigned to Ge–O and Ge–O–Ge vibrations. Gaussian deconvolution and intensity ratio analysis further supported the presence of germanate species and their interaction with the hybrid matrix. SEM analysis revealed the formation of a continuous microstructured coating covering the titanium surface, while EDS mapping confirmed the presence and distribution of Ca, P, Ge and other constituent elements within the deposited layer. The obtained results demonstrate that Na_2GeO_3 was successfully incorporated into the ACP/ChOL coating and structurally integrated within the amorphous calcium phosphate/chitosan matrix. These hybrid coatings represent a promising platform for multifunctional titanium surface modification in biomedical applications.

Keywords: *titanium implants; hybrid coatings; calcium phosphate coatings; bioactive materials*

Intermolecular Interactions and Dexamethasone Incorporation in ACP/ChOL Coatings on Titanium

Marijana R. Pantović Pavlović[1,*], Katarina Đ. Božić[1], Miloš M. Lazarević[2], Nenad L. Ignjatović[3], Miroslav M. Pavlović[1]

[1]*University of Belgrade, Institute of Chemistry, Technology and Metallurgy - National Institute of the Republic of Serbia, Department of Electrochemistry, Belgrade, Serbia*

[2]*University of Belgrade, School of Dental Medicine*

[3]*Institute of Technical Science of the Serbian Academy of Sciences and Arts, Belgrade, Serbia*

[*]*m.pantovic@ihtm.bg.ac.rs*

Abstract

Amorphous calcium phosphate/chitosan oligosaccharide lactate (ACP/ChOL) composite coatings containing dexamethasone (DEX) were electrophoretically deposited on titanium substrates in order to obtain multifunctional bioactive surfaces with potential application in implantology and localized drug delivery. The influence of dexamethasone concentration and deposition time on the structural and chemical properties of the coatings was investigated using Fourier transform infrared spectroscopy (FTIR), energy-dispersive spectroscopy (EDS), and surface characterization methods. FTIR analysis confirmed successful incorporation of DEX into the ACP/ChOL matrix through characteristic spectral changes, including broadening and asymmetry of the O–H stretching region, appearance of additional C–H contributions around ~2950 cm^{-1}, modifications of carbonyl/enone-related bands (~1700 and ~1630 cm^{-1}), and distinct changes in the fingerprint region. Gaussian deconvolution and Δν analysis revealed intermolecular interactions between DEX, chitosan oligosaccharide lactate, and amorphous calcium phosphate, indicating molecular-level dispersion of DEX within the coating rather than formation of a separate crystalline phase. Increasing deposition time and DEX concentration led to more pronounced broadening of phosphate- and hydroxyl-related bands, suggesting enhanced incorporation of DEX and restructuring of the hydrogen-bonding network within the composite coating. The obtained results demonstrate that electrophoretically deposited ACP/ChOL/DEX coatings represent promising multifunctional systems for titanium surface functionalization, combining bioactive calcium phosphate phases with controlled corticosteroid incorporation.

Keywords: *titanium surface modification; drug delivery; hybrid coatings; bioactive materials*

Tailoring Oxygen Evolution Activity of Rare Earth-Containing Electrocatalysts

Miroslav M. Pavlović[1,*], Katarina Đ. Božić[1], Vladimir V. Panić[1,2], Srećko Stopić[3], Marijana R. Pantović Pavlović[1]

[1]*University of Belgrade, Institute of Chemistry, Technology and Metallurgy - National Institute of the Republic of Serbia, Department of Electrochemistry, Belgrade, Serbia*

[2]*State University of Novi Pazar, Novi Pazar, Serbia*

[3]*Institute for Process Metallurgy and Metal Recycling, RWTH Aachen University, Aachen, Germany*

[*]*miroslav.pavlovic@ihtm.bg.ac.rs*

Abstract

The oxygen evolution reaction (OER) remains the primary kinetic bottleneck in electrochemical water splitting due to its complex multi-electron transfer mechanism and the high overpotentials required to sustain industrially relevant current densities. The development of efficient, durable, and economically viable electrocatalysts is therefore essential for the advancement of hydrogen production technologies and other energy-conversion systems. Although iridium- and tantalum-based oxides are among the most active OER catalysts in acidic media, their scarcity and high cost significantly limit large-scale deployment.

In this work, a versatile one-step ultrasonic spray pyrolysis (USP) approach was employed for the synthesis of rare-earth-containing multimetallic oxide materials intended for oxygen evolution electrocatalysis. The developed materials incorporated rare-earth elements (Ce, Y, Yb, and Dy) together with transition metals, primarily Co and Mn, and were designed either as standalone catalytic materials or as functional cores in advanced core–shell architectures containing Ir-based surface layers. The USP process enabled the preparation of compositionally controlled spherical oxide particles with tunable morphology and physicochemical properties while maintaining a scalable and industrially relevant synthesis route.

The influence of composition, thermal treatment, and metal ratios on the electrochemical behavior of the synthesized materials was investigated using non-faradaic electrochemical measurements, capacitance analysis, particle-size characterization, and oxygen evolution testing. The results demonstrated that rare-earth oxides play a significant role in tailoring charge-storage characteristics, surface interactions, and catalyst stability. Y-rich oxide cores promoted a more homogeneous distribution of the Ir-oxide shell and improved electrochemical response, while cobalt-containing systems exhibited enhanced OER activity through synergistic interactions between transition-metal and rare-earth components. Furthermore, optimized core–shell structures enabled efficient utilization of iridium, reducing the amount of noble metal required without compromising catalytic performance.

The obtained findings demonstrate that rational integration of rare-earth and transition-metal oxides represents an effective strategy for designing high-performance oxygen-evolving electrocatalysts. The proposed USP-based platform provides a scalable pathway toward durable and cost-effective OER materials suitable for water electrolysis, regenerative fuel cells, and metal–air battery technologies, while simultaneously reducing dependence on critical noble metals.

Keywords: *electrocatalysis; oxygen evolution reaction; sustainable energy; water electrolysis*

Optimization of Processing Parameters in Kaolin–Fly Ash Ceramics

Vojo Jovanov[1,*], Otton Roubinek[2], Biljana Angjusheva[1]

[1]*Ss. Cyril and Methodius University in Skopje, Faculty of Technology and Metallurgy, Ruger Bosković 16, 1000 Skopje, Republic of North Macedonia*

[2]*Łukasiewicz–Industria Chemiatria Instytutem, Departament of Pharmacy, Cosmetic Chemistry and Biotechnology, Warsaw, Poland*

[*]*vojo@tmf.ukim.edu.mk*

Abstract

The present study evaluates the combined effects of composition, mechanical activation of fly ash (FA), and sintering temperature on the densification and Young's modulus of kaolin-based ceramics. Four compositions (100% kaolin, 90K–10FA, 75K–25FA, and 50K–50FA) were investigated within the temperature range of 1000–1200°C and mechanical activation times of 0–30 min. The experimental data were analyzed using a General Linear Model (GLM).

The results indicate that sintering temperature is the dominant factor governing densification and stiffness. Composition also plays a key role, with 10–25wt.% FA promotes improved densification and Young's modulus, while higher FA (50wt.%) content leads to reduced density. Mechanical activation exhibited a limited influence on densification but contributed to improved elastic properties.

Optimal processing conditions were identified at 1200°C, with 75K–25FA composition and 15–30 min activation time.

Keywords: *Kaolin; Fly ash; Mechanical activation; Sintering; Densification; Young's modulus*

Izvod

Ова студија процењује комбиноване ефекте састава, механичке активације летећег пепела (FA) и температуре синтеровања на згушњавање и Јангов модул еластичности керамике на бази каолина. Четири састава (100% каолин, 90K–10FA, 75K–25FA и 50K–50FA) су испитивана у температурном опсегу од 1000–1200°C и временима механичке активације од 0–30 минута. Експериментални подаци су анализирани коришћењем Општег линеарног модела (GLM).

Резултати указују да је температура синтеровања доминантан фактор који регулише згушњавање и крутост. Састав такође игра кључну улогу, при чему 10–25 теж.% FA подстиче побољшано згушњавање и Јангов модул еластичности, док већи садржај FA (50 теж.%) доводи до смањења густине. Механичка активација је показала ограничен утицај на згушњавање, али је допринела побољшаним еластичним својствима.

Оптимални услови обраде су идентификовани на 1200°C, са саставом 75K–25FA и временом активације од 15–30 минута.

Ključne reči: *Летећи пепео; Механичка активација; Синтеровање; Згушњавање; Јангов модул еластичности*

Corrosion Performance of Cast Aluminum Alloys for Electric Vehicles

Marija Mihailović[1,*], Mile B. Djurdjevic[2], Srecko Manasijevic[3], Aleksandra Patarić[1]

[1]*University of Belgrade - Institute of Chemistry, Technology and Metallurgy - National Institute of the Republic of Serbia, Njegoševa 12, Belgrade, Serbia*

[2]*METALTHERMO, Bulevar umetnosti 17, 11070 Belgrade, Serbia*

[3]*Lola Institute, Belgrade, Serbia*

[*]*marija.mihailovic@ihtm.bg.ac.rs*

Abstract

The growing production of electric vehicles (EVs) has created an increasing need for cast aluminum alloys with superior corrosion resistance. In comparison with components used in conventional combustion engines, EV cast parts including battery enclosures, electric motor housings, and stator covers are exposed to lower operating temperatures, confined environments, and enhanced moisture condensation, which accelerate corrosion-related degradation. This paper examines the corrosion behavior of cast Al-Si alloys intended for EV applications, with particular attention given to the effects of copper (Cu), iron (Fe), and magnesium (Mg) on alloy performance.

Copper is recognized as the most critical alloying element affecting corrosion resistance in EV aluminum castings. The formation of Al_2Cu phases along grain boundaries increases susceptibility to intergranular corrosion, particularly in areas exposed to sealing interfaces and electrical contacts. For this reason, the Cu concentration in corrosion-sensitive components should remain below 0.05 wt.%. Iron also negatively influences corrosion behavior by promoting pitting through the formation of cathodic β-Al_5FeSi intermetallic compounds. Nevertheless, the addition of manganese can mitigate this effect by transforming the detrimental needle-like β-phases into more compact α-phases, thereby lowering the tendency for localized corrosion initiation.

Magnesium plays a complex role in these alloys. Although Mg_2Si precipitation contributes significantly to mechanical strengthening, excessive Mg levels or improper heat treatment conditions may enhance grain boundary corrosion. An optimized Mg content in the range of 0.25–0.45 wt.% together with suitable heat treatment conditions provides a favorable compromise between corrosion resistance and mechanical properties.

Besides corrosion performance, EV cast components are also required to meet strict demands related to mechanical strength, dimensional stability, electromagnetic shielding capability, and crash resistance. Balancing these interconnected properties represents a major challenge in alloy and casting design. Low-Cu Al-Si-Mg alloys, therefore appear to be among the most suitable candidates for corrosion-sensitive EV applications.

Keywords: *corrosion resistance; Al-Si alloys; copper; iron; magnesium*

Acknowledgements

This research has been financially supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (Contract No. 451-03-33/2026-03/200026 and 451-03-33/2026-03/200066). The work aligns with United Nations Sustainable Development Goal #7: Ensure access to affordable, reliable, sustainable, and modern energy for all.

Thermal Analysis-Based Model for Predicting Hot Tearing Susceptibility in Hypoeutectic Al-Si-Cu Alloys

Marija Mihailović[1,*], Srecko Manasijevic[2], Aleksandra Patarić[1], Mile B. Djurdjevic[3]

[1]*University of Belgrade - Institute of Chemistry, Technology and Metallurgy - National Institute of the Republic of Serbia, Njegoševa 12, Belgrade, Serbia*

[2]*Lola Institute, Belgrade, Serbia*

[3]*METALTHERMO, Bulevar umetnosti 17, 11070 Belgrade, Serbia*

[*]*marija.mihailovic@ihtm.bg.ac.rs*

Abstract

This paper provides an overview of the main factors governing hot tearing formation in hypoeutectic Al-Si-Cu casting alloys and proposes an advanced analytical method for evaluating crack susceptibility. Four alloys with different copper contents, namely Cu in the range 1-4 wt%, were investigated to determine the effect of Cu addition on hot tearing tendency. The influence of strontium modification on crack formation was also analyzed.

Thermal analysis using cooling curves was employed to obtain characteristic solidification parameters. Based on these results, a model for predicting the crack susceptibility coefficient (CSC) was introduced. Unlike the conventional Clyne and Davies approach, the proposed method incorporates the critical solidification interval between coherency and rigidity points, representing the stage where alloys are most vulnerable to hot tearing.

To validate the model, the calculated CSC values were compared with experimental hot cracking index (HCI) data available in the literature for AlSi7Mg0.1Cu0.005, AlSi7Mg0.3Cu0.05, and AlSi7Mg0.6Cu0.05 alloys. A strong correlation between theoretical predictions and experimental observations was obtained.

The proposed methodology offers important practical advantages for industrial casting applications, as it allows calculations based on both temperature and time criteria while considering the effects of cooling conditions and alloy chemistry on solidification behavior. Incorporating thermal analysis data significantly improves the understanding of mushy zone evolution and the role of alloying elements in hot tearing formation.

In addition, the parameters obtained through cooling curve analysis can be integrated into existing casting simulation software, enabling more reliable prediction of defect formation, optimization of processing conditions, and improved casting quality with reduced production losses.

Keywords: *crack susceptibility coefficient; copper; strontium; Al lloys*

Acknowledgments

This research has been financially supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (Contract No. 451-03-33/2026-03/200026 and 451-03-33/2026-03/200066). The work aligns with United Nations Sustainable Development Goal #7: Ensure access to affordable, reliable, sustainable, and modern energy for all.

Development of a β-MnO_2 Electrochemical Sensor for the Detection of Trace Heavy Metals in Water

Aleksandar M. Đorđević[1,*], Kristina Radinović[2], Mirjana Mališić[2], Ivana Stojković Simatović[2], Nikola Cvjetićanin[2] and Biljana Šljukić[2,3]

[1]*Institute of General and Physical Chemistry, Studentski tg 12/V, 11158 Belgrade, Serbia*

[2]*University of Belgrade, Faculty of Physical Chemistry, Studentski trg 12-16, 11158 Belgrade, Serbia*

[3]*Center of Physics and Engineering of Advanced Materials, Laboratory for Physics of Materials and Emerging Technologies, Chemical Engineering Department, Instituto Superior Técnico, Universidade de Lisboa, Lisbon, Portugal*

[*]*adjordjevic@iofh.bg.ac.rs*

Abstract

The presence of heavy metals in water represents a serious environmental and public health issue due to their high toxicity, persistence, and ability to bioaccumulate in living organisms. Among the most significant pollutants are lead and cadmium ions, whose presence even at very low concentrations may cause harmful effects on human health and the environment. Therefore, there is a growing need for the development of rapid, sensitive, reliable, and cost-effective methods for their determination in water samples. In this study, the applicability of a carbon electrode modified with β-MnO_2 material for the electrochemical determination of Pb^{2+} and Cd^{2+} ions using linear stripping voltammetry was investigated. B-MnO_2 was selected as a promising sensing material due to its favorable electrochemical properties, chemical stability, and low cost. Electrochemical measurements were performed in a supporting electrolyte containing 20 mM H_2SO_4 and 30 mM KCl, within the concentration range from 5 to 50 μM, under optimized deposition conditions of 120 s at a deposition potential of -1.0 V. The obtained results demonstrated that the β-MnO_2 modified electrode enables successful detection of both Pb^{2+} and Cd^{2+} ions. The oxidation peak for Pb^{2+} appeared at approximately -0.42 V, while the oxidation peak for Cd^{2+} was observed at around –0.75 V. An increase in ion concentration resulted in a linear increase of the current response within the investigated concentration range. The limit of detection for Pb^{2+} ions was 6.5 μg dm^{-3}, whereas for Cd^{2+} ions it was determined to be 2.6 μg dm^{-3}. In addition, the possibility of simultaneous detection of both metal ions was successfully demonstrated, with clearly separated oxidation peaks characteristic for Pb^{2+} and Cd^{2+} ions. The obtained results indicate that the β-MnO_2 modified carbon electrode represents a promising material for the development of electrochemical sensors intended for the determination of trace heavy metals in real water samples.

Keywords: *electrochemical sensors; lead; cadmium; manganese dioxide*

Izvod

Prisustvo teških metala u vodi predstavlja ozbiljan ekološki i zdravstveni problem zbog njihove izražene toksičnosti, postojanosti i mogućnosti bioakumulacije u živim organizmima. Među najznačajnijim zagađivačima izdvajaju se joni olova i kadmijuma, čije prisustvo čak i u veoma niskim koncentracijama može izazvati štetne efekte po zdravlje ljudi i životnu sredinu. Zbog toga postoji potreba za razvojem brzih, osetljivih, pouzdanih i ekonomičnih metoda za njihovo određivanje u vodenim uzorcima. U ovom radu ispitana je mogućnost primene ugljenične elektrode modifikovane β-MnO_2 materijalom za elektrohemijsko određivanje Pb^{2+} i Cd^{2+} jona metodom linearne stripping-voltametrije. β-MnO_2 je izabran kao potencijalni senzorski materijal zbog dobrih elektrohemijskih svojstava, hemijske stabilnosti i povoljne cene. Elektrohemijska merenja izvršena su u osnovnom

elektrolitu sastava 20 mM H_2SO_4 i 30 mM KCl, u koncentracionom opsegu od 5 do 50 μM, uz optimizovane uslove depozicije od 120 s pri potencijalu od -1,0 V. Dobijeni rezultati pokazali su da β-MnO_2 modifikovana elektroda omogućava uspešnu detekciju Pb^{2+} i Cd^{2+} jona. Oksidacioni pik za Pb^{2+} javlja se na približno -0,42 V, dok se za Cd^{2+} oksidacioni pik registruje na oko -0,75 V. Sa povećanjem koncentracije analiziranih jona dolazi do linearnog porasta strujnog odgovora u ispitivanom koncentracionom opsegu. Granica detekcije za Pb^{2+} jone iznosila je 6,5 μg dm^{-3}, dok je za Cd^{2+}određena vrednost od 2,6 μg dm^{-3}. Takođe, uspešno je demonstrirana mogućnost simultane detekcije oba metala, pri čemu su dobijeni jasno razdvojeni oksidacioni pikovi karakteristični za Pb^{2+} i Cd^{2+} jone. Dobijeni rezultati ukazuju da β-MnO_2 modifikovana ugljenična elektroda predstavlja perspektivan materijal za razvoj elektrohemijskih senzora namenjenih određivanju teških metala u tragovima u realnim vodenim uzorcima.

Ključne reči: *elektrohemijski senzori; olovo; kadmijum; mangan-dioksid*

Acknowledgments

The authors acknowledge the financial support from the Ministry of Science, Technological Development, and Innovation of the Republic of Serbia (contract no. 451-03-34/2026-03/200146, 451-03-33/2026-03/200146), as well as Fundaçãao para a Ciência e a Tecnologia (FCT, Portugal) (funding under contract LA/P/0095/2020, LaPMET).

AUTHOR INDEX

Authors are listed in the format Surname, Name/initials. Page numbers refer to the Proceedings page numbering.

J

K

L

M

N

P

R

S

T

U

V

Z

Đ

Š

SPONSORS

SPONZORI

GOLD SPONSOR

ZLATNI SPONZOR

GRADIMO BUDUĆNOST. ČUVAMO TRADICIJU.

od 1950. godine

ANTIKOROZIVNA ZAŠTITA

Peskiranje
Protivpožarna zaštita

Akreditovana laboratorija
za ispitivanje premaza

www.jadran-bg.rs

Peskiranje Beograd

Peskiranje_Beograd

Ne štitimo samo čelik i konstrukcije.
Štitimo investicije, bezbednost i vek trajanja objekata.

JADRAN

GRADIMO BUDUĆNOST. ČUVAMO TRADICIJU.

TRADICIJA KOJA GRADI BUDUĆNOST

Pre više od sedam i po decenija, iz okrilja građevinskog kombinata Komgrap, nastala je kompanija čija se snaga nikada nije merila samo kvadratima i tonama ili tehničkim parametrima. Od samog početka, Jadran je gradio sistem vrednosti zasnovan na znanju, odgovornosti i poštovanju struke.

Od prvih projekata u bivšoj Jugoslaviji do gradilišta u Egiptu, Rusiji, Alžiru i Iraku, Jadran je gradio reputaciju pouzdanog partnera sposobnog da odgovori na najsloženije izazove. Sedamdesete i osamdesete godine ostale su upamćene kao zlatno doba Jadrana. To je period u kome su radnici sa ponosom pronosili ime kompanije, a pripadnost kolektivu značila je stabilnost, ugled i lični razvoj. Znanje se prenosilo neposredno – sa iskusnih majstora i inženjera do novih generacija koje danas vode projekte u digitalnom okruženju, koristeći savremene tehnologije i alate.

Danas Jadran okuplja više od 800 stručnjaka različitih profila i posluje kao integrisani sistem za projektovanje, izvođenje i upravljanje kompleksnim građevinskim procesima.

Više od pola veka iskustva u antikorozivnoj zaštiti

Antikorozivna zaštita predstavlja jednu od naših ključnih delatnosti, sa tradicijom dugom više od pola veka. Prve velike projekte realizovali smo na objektima poput Hidroelektrana Đerdap I i Termoelektrana Nikola Tesla, čime smo postavili temelje stručnosti i pouzdanosti po kojima smo danas prepoznati.

Tokom godina sarađivali smo sa najznačajnijim energetskim i industrijskim sistemima u zemlji – Srbijagas, Elektroprivreda Srbije, Elektromreže Srbije i NIS – kao i sa brojnim privatnim investitorima.

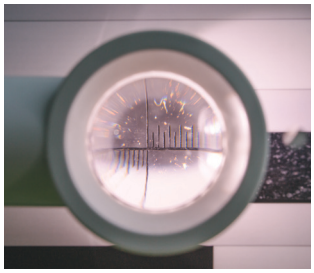
Raspolažemo timom iskusnih inženjera, rukovodilaca projekata i majstora specijalizovanih za pripremu površina i nanošenje zaštitnih sistema. Koristimo savremenu opremu za kontrolu mikroklimatskih uslova, obradu podloge, aplikaciju premaza i ispitivanje kvaliteta očvrslih slojeva, čime obezbeđujemo potpunu kontrolu procesa.

Izvodimo zaštitu čeličnih konstrukcija i industrijske opreme u energetici, građevinarstvu, hemijskoj, naftnoj i gasnoj industriji, metalurgiji, brodogradnji i saobraćajnoj infrastrukturi. Primenom odgovarajućih sistema produžavamo vek trajanja objekata izloženih zemlji, vodi, agresivnoj atmosferi i drugim korozivnim uticajima, u skladu sa važećim domaćim i međunarodnim standardima.

Za zaštitu čeličnih konstrukcija primenjujemo i protivpožarne sisteme, uključujući premaze za kablovske regale i vodove. Intumescentni materijali pri visokim temperaturama formiraju izolacioni sloj koji usporava zagrevanje čelika i obezbeđuje potrebno vreme za bezbednu evakuaciju. Debljina premaza određuje se projektom i zavisi od tipa profila, režima gorenja (celulozno ili ugljovodonično) i zahtevanog vremena otpornosti konstrukcije.

Pouzdana zaštita počinje mnogo pre nanošenja.
Počinje preciznim merenjima, kontrolom i stručnim ispitivanjem.

U okviru sistema kontrole kvaliteta posedujemo sopstvenu **Akreditovanu laboratoriju** za ispitivanje premaza, što predstavlja ključnu garanciju pouzdanosti izvedenih radova. Laboratorija je opremljena savremenom opremom za hemijska, fizička, mehanička i nerazorna ispitivanja, a obim rada obuhvata 14 standardizovanih metoda. Ispitivanja realizuju iskusni inženjeri, osposobljeni za najzahtevnije projekte.



Metode ispitivanja:

- Ocenjivanje prisustva prašine na površinama čelika pripremljenim za bojenje prema SRPS EN ISO 8502-3:2017
- Metoda za stepenovanje profila površine čelika očišćenog mlazom abraziva — Postupak pomoću komparatora prema SRPS EN ISO 8503-2:2013
- Metoda replike na prianjajućoj traci za određivanje profila površine prema SRPS EN ISO 8503-5:2017
- Ispitivanje hrapavosti površine metodom ubodne igle prema ASTM D4417-21
- Procenjivanje verovatnoće nastajanja kondenzacije pre nanošenja boje prema SRPS EN ISO 8502-4:2017
- Ekstrakcija zagađivača rastvorljivih u vodi za analize – Metoda po Breslu prema SRPS EN ISO 8502-6:2020
- Konduktometrijsko određivanje soli rastvorljivih u vodi na terenu prema SRPS EN ISO 8502-9:2020
- Određivanje debljine suvog filma prema SRPS EN ISO 2808:2019
- Merenje i kriterijumi za prihvatanje debljine suvih filmova na hrapavim površinama prema SRPS ISO 19840:2017
- Ocenjivanje poroznosti suvog filma prema SRPS EN ISO 29601:2013
- Ispitivanje unakrsnim prosecanjem prema SRPS EN ISO 2409:2020
- Ispitivanje unakrsnim prosecanjem i ispitivanje prosecanjem oznake u obliku X prema SRPS EN ISO 16276-2:2010
- Ispitivanje prianjanja otkidanjem prema SRPS EN ISO 4624:2023
- Ocenjivanje i kriterijumi prihvatanja za prianjanje/koheziju (jačinu kidanja) prevlake – Deo 1: Ispitivanje otkidanjem prema SRPS EN ISO 16276-1:2010

SILVER SPONSORS

SREBRNI SPONZORI

“MC Labor d.o.o Beograd”, osnovan 2005. godine, je od svog osnivanja orijentisan na trgovinu **laboratorijskom i procesnom mernom opremom** koja je namenjena praćenju različitih parametara kvaliteta proizvoda. Prodajna ponuda preduzeća naslanja se na proizvodni portfolio naših inopartnera:

“ANTON PAAR”GmbH

-Denzitometri, NIR analizatori za pića, automatski sistemi za analizu pića (piva, vina, žestokih I osvećavajućih pića),

-Određivanje sadržaja CO2, O2 i TPO u pićima,

-Refraktometri, polarimetri, automatizovani sistemi za analizu stepena digestije,

-Viskozimetri (rotacioni, falling-ball, automatski kinematski viskozimetri) ,

-Reometri svih klasa sa najširom paletom dostupnih alata na tržištu ,

-Mikrotalasna priprema uzoraka – digestija za rutinske ili visokozahtevne uzorke, ekstrakcija, evaporacija,

-Mikrotalasna sinteza od gramskog do kilogramskog prinosa, sinteza sa Ramanovom sondom za praćenje toka hemijske reakcije,

-Merači veličine čestica od nano do milimetarskog nivoa,

-Porometri, gasni adsorberi za određivanje BET specifične površine, veličine I zapremine pora sa ili bez masenog spektrometra, gasni piknometri za merenje gustine čvrstih materijala,

-Uređaji za određivanje tvrdoće u oblasti ultranano I nano opterećenja, scratch testeri, tribometri, kalotest,

- Ispitivanje oksidacione stabilnosti,

-Različita oprema iz petrohemijskog segmenta (destilacija, tačke paljenja u skladu sa različitim standardima, automatsko određivanje kinematičkog viskoziteta I indeksa viskoznosti, CFPP, BPA itd.)

-Penetrometri,

-Raman spektrometri,

-FTIR uređaji (specijalizovani/opšti),

-Diferencijalno skenirajući kalorimetri,

-XRD uređaji sa velikim izborom ambijentalnih I neambijentalnih komora,

-SAXS uređaji,

-široke mogućnosti automatizacije I robotizacije većine navedenih postupaka.

“BRABENDER – A brend of Anton Paar”

U okviru svoje **Food & Feed** podgrupe proizvodi široku paletu reoloških uredjaja (farino, ekstenzo I amilograf) za profilisanje kvaliteta brašna, mlinove različitih namena u skladu sa relevantnim standardima , dok u podgrupi

Plastic & Rubber proizvodi široku paletu uređaja za kontrolu kvaliteta standardizovanih uređaja kao što su: Aquatrac-V (merenje sadržaja vlage /rezidualne vode u polimerima),

Absorptometer (analize čađi I silicijum-dioksida – OAN broj), TSSR-meter (uređaji za karakterizaciju elastomera I određivanje crosslinking gustine), Elatest (za određivanje gustine polimera, pogotovu kod gume I nevulkanizovanih gumenih jedinjenja).

Obe podgrupe ovog renomiranog proizvođača proizvode sjajne Miksere I ekstrudere (single screw I twin screw ekstrudere), različitih kapaciteta , dizajnirane za različite potrebe.

Grupacija "KPM ANALYTICS"

-Oprema za reološku kontrolu brašna (testa) -CHOPIN,

-Automatizovano ispitivanje površinskih, pijaćih I otpadnih voda, zemljišta, đubriva, pića, duvana -AMS;

-NIR analizatori za sve industrijske grane- Unity, Bruins, Process Sensor;

-Vizuelni nadzor linija-SightLine, EyePro Techn.

"HITACHI" grupacija

-široka gama uređaja za termijsku analizu – DSC, STA/TGA, STA-FTIR, DMA/TMA,

-ED XRF uređaji (brza, nedestruktivna, elementarna analiza metala, ruda, zemljišta – ručni I laboratorijski uređaji,

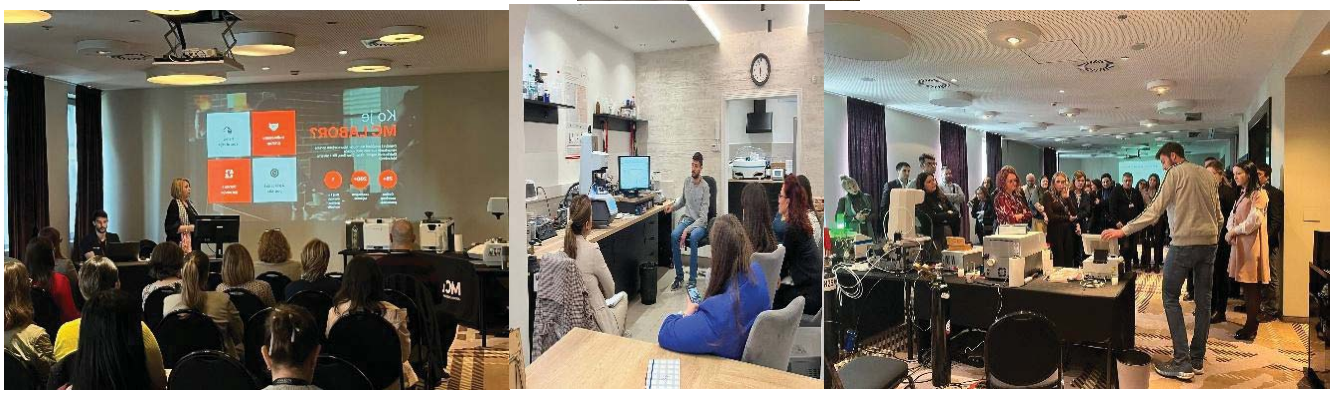
-ED XRD analizatori za određivanje hemijskog sastava I debljine prevlaka,
-LIBS analizatori,
-OES analiza metala/legura – stacionarni I pokretni modeli,

“EQUILAB”

-Aparati za pripremu uzoraka za dalju analitičku obradu kao što su mlinovi, prese, flukseri.

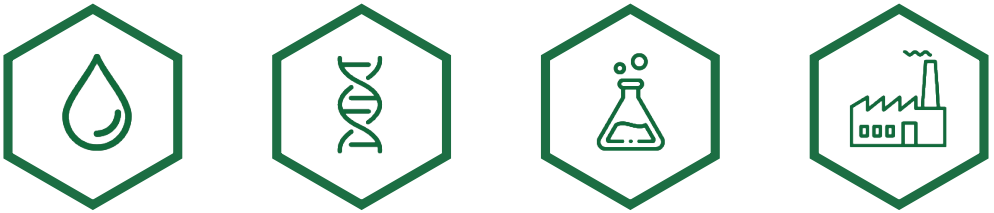
Teritorija našeg delovanja je, u zavisnosti od proizvođača, od Srbije I Crne Gore, pa do ostalih zemalja sa prostora exYU.Za svu opremu koju isporučujemo pružamo potpunu podršku od instalacije, obuke kadra za rad pa do aplikativne podrške I servisa u garantnom I vangarantnom roku.

Vaš **MC Labor** tim,
office@mclabor.co.rs, www.mclabor.co.rs
Mob. 060 333 13 03
Dobanovačka 101, 11080 Zemun, Beograd



KRUG INTERNATIONAL LTD.

KRUG



LABORATORIJSKI INSTRUMENTI I OPREMA ZA:

FARMACEUTSKU
PETROHEMIJSKU
BIOTEHNOLOŠKU
RUDARSKU
PREHRAMBENU
I OSTALE INDUSTRIJE

PREKO 30 GODINA ZASTUPAMO PROIZVOĐAČE NAJSAVREMENIJIH LABORATORIJSKIH I ANALITIČKIH UREĐAJA

NUDIMO KOMPLETNU SERVISNU PODRŠKU I VALIDACIJU INSTRUMENATA

MALVERN PANALYTICAL

MALVERN PANALYTICAL je renomirana kompanija koja nudi kompletan program za fizičku karakterizaciju materijala. Njihove tehnologije koriste naučnici i inženjeri u širokom spektru industrija. Fokus je na stvaranju inovativnih rešenja usmerenih na korisnike radi bolje efikasnosti u hemijskoj, fizičkoj i strukturnoj analizi materijala.

MALVERN PANALYTICAL instrumenti su dizajnirani da pomognu boljem razumevanju i analizi materijala, od proteina i polimera, suspenzija čestica, nano čestica i emulzija, do sprejeva i aerosola, industrijskih praškova, minerala i visoko koncentrovanih suspenzija i čvrstih materija, kao što su metali i građevinski materijali, plastika i polimeri.

Ove tehnologije omogućuju merenje parametara uključujući veličinu čestica, oblik i koncentraciju, hemijski identitet, zeta potencijal, molekulsku masu, biomolekulske interakcije i stabilnost, elementalne koncentracije i kristalografske strukture.

IZDVAJAMO:

MASTERSIZER 300+
ZETASIZER ADVANCE
AERIS
EMPYREAN
ZETIUM
EPSILON RANGE

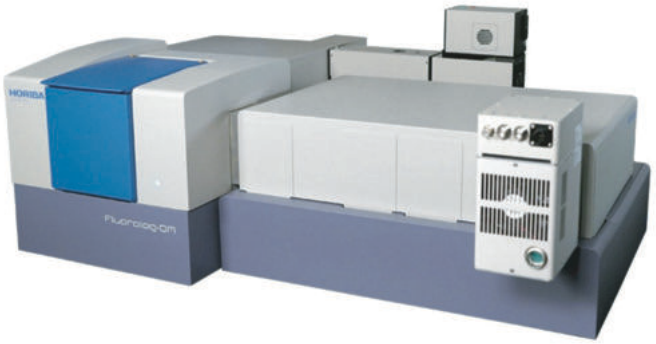
Malvern Panalytical

HORIBA je kompanija sa tradicijom dugom 200 godina i bavi se proizvodnjom spektrometrijskih i spektroskopskih analizatora raznih tipova i namena.

Vodeći su u svetu po broju naučnih radova objavljenih upotrebom njihovih analizatora. Sarađuju sa vodećim naučnim institucijama – NASA, CERN, MIT, École Polytechnique. Njihov portfolio sadrži sledeće tehnike: Raman spektrometri, Fluorimetri, ICP spektrometri, GD-OES, PP-TOFMS, Atomic Force mikroskopi (AFM), elementalni analizatori.

IZDVAJAMO:

RAMAN
AFM OPT
SPEKTROFLUORIMETAR
GDOES
ELEMENTALNI ANALIZTORI
ELIPSOMETRIJA



HORIBA

LINSEIS

Od 1957. godine nemačka kompanija LINSEIS razvija i proizvodi sofisticiranu i preciznu opremu za termalnu i termalno-fizičku analizu prema najvišim standardima.
Zadovoljstvo kupaca, inovativnost, fleksibilnost i visok kvalitet su ono što LINSEIS izdvaja od drugih proizvođača iste vrste opreme. Zahvaljujući navedenim karakteristikama LINSEIS uživa izuzetan ugled među vodećim naučnim i industrijskim organizacijama širom sveta.

LINSEIS podržava aplikacije u sektorima kao što su polimeri, hemijska industrija, neorganski građevinski materijali, analitika životne sredine itd. Između ostalog moguće je analizirati termofizička svojstva čvrstih materija, tečnosti i rastopa. Inovativni pristup i preciznosti čine LINSEIS vodećim svetskim proizvođaćem opreme za termalnu analizu.

IZDVAJAMO:

TERMALNE ANALIZATORE (DSC, TGA, STA)
DILATOMETRE
APARATE ZA ISPITIVANJE TERMALNE PROVODLJIVOSTI
APARATE ZA ISPITIVANJE ELEKTRIČNIH OSOBINA MATERIJALA (LSR, HCS, ANALIZA TANKIH FILMOVA , TEG TESTERI)

LINSEIS

Nemačka kompanija KNAUER proizvodi vrhunske naučne instrumente za istraživanje, rutinsku analizu, kontrolu kvaliteta i druge primene.

Podržane tehnologije uključuju tečnu hromatografiju, precizno rukovanje i pumpanje tečnosti pod visokim pritiscima, opremu za proizvodnju LNP čestica.

IZDVAJAMO:

(U)HPLC
PREP.LC
FPLC
SMB
LNP
OSMOMETRIJA

KNAUER

LINETRONIC TECHNOLOGIES

LINETRONIC TECHNOLOGIES S.A. je švajcarska kompanija koja se bavi proizvodnjom opreme za analizu nafte i naftnih derivata.

U svom programu imaju automatske, poluautomatske i ručne analizatore.
Koriste se u naftnoj industriji, kontrolno-inspekcijskim laboratorijama, hemijskoj industriji, farmaceutskoj industriji, carinskim laboratorijama. LINETRONIC instrumenti su konstruisani i bazirani na osnovu analitičkih metoda po ASTM, IP, ISO, EN, DIN standardima.

IZDVAJAMO:

APARAT ZA ODREĐIVANJE TAČKE PALJENJA
APARAT ZA ODREĐIVANJE KOROZIJE BAKARNOM TRAKOM
PENETROMETAR
ANALIZATOR ZA ODREĐIVANJE TAČKE MRŽNJENJA
APARAT ZA DESTILACIJU NAFTNIH PROIZVODA

LINETRONIC TECHNOLOGIES

Vodeća rešenja za disoluciju.

DISTEK je fokusiran na instrumente za ispitivanje rastvaranja doziranih formi (tableta, kapsula, gelova), u okviru sektora istraživanja i razvoja i kontrole kvaliteta. Tokom 45 godina, sa razvojem Disteka, teklo je i širenje poslovanja, u pravcu ponude instrumenata za druga ispitivanja koja se obavljaju u farmaceutskim laboratorijama. Kao lider u svojoj oblasti, DISTEK ima izvanrednu reputaciju u pogledu inovativnosti i pouzdanosti proizvoda.

IZDVAJAMO:

DISOLUCIONE SISTEME
DISOLUCIONE AUTOSEMPLERE
SISTEME ZA DEZINTEGRACIJU

DISTEK
CREATING A STIR

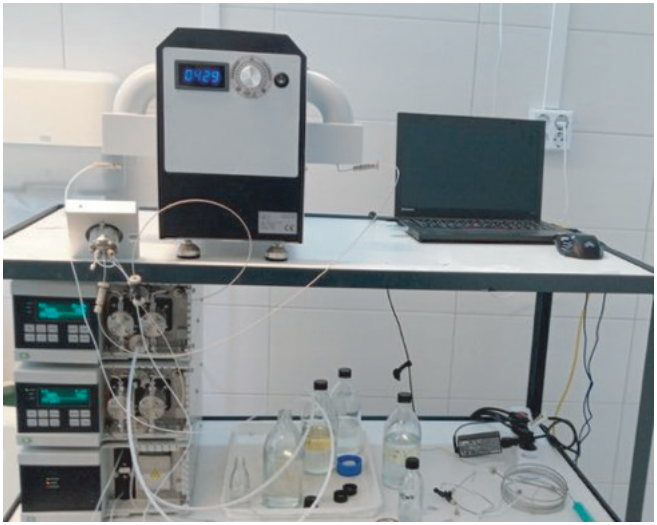
LILICHRO

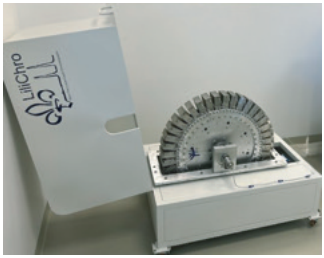
Rešenja za tečnu-tečnu hromatografiju nezavisno od veličine projekta.

Hromatografija je precizna i skupa tehnika koja je osnova za prečišćavanje aktivnih sastojaka. Dok je upotreba hromatografije u analitičke svrhe široko rasprostranjena, primene u industrijskom obimu su bile ograničene zbog visokih troškova. Do 2015. godine jedino industrijsko rešenje bila je preparativna hromatografija nakon čega se kao prekretnica prvi put pojavio industrijski CPC - Centrifugalni particioni hromatograf postavljajući nove standarde u prečišćavanju aktivnih sastojaka.

IZDVAJAMO:

MINILILI KAO ANALITIČKO REŠENJE U OPSEGU U MILIGRAMIMA
MIDILILI KAO REŠENJE ZA RAD U OPSEGU U GRAMIMA
MAXILILI KAO PILOT REŠENJE GDE SE RADI O OPSEZIMA U KILOGRAMIMA
PREPLILI KAO INDUSTRIJSKO REŠENJE NA SKALI U TONAMA



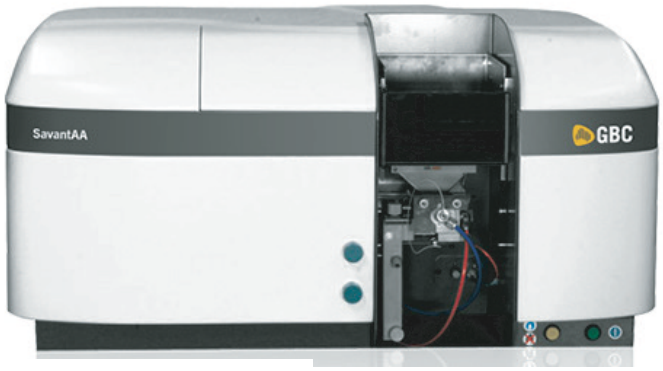


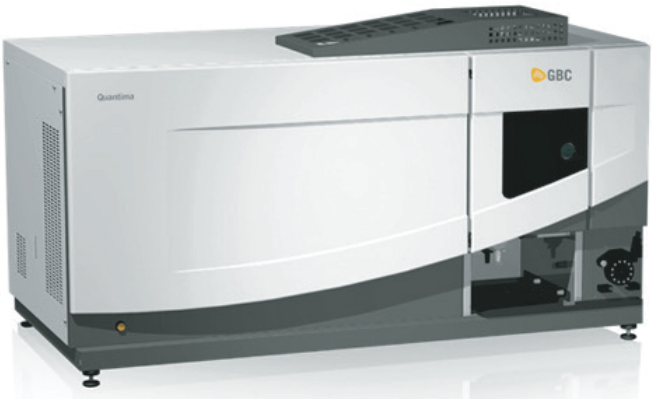
LiliChro

GBC je renomirani australijski proizvođač analitičkih instrumenata koja uključuje atomske apsorpcione spektrometre (AAS) i UV/VIS spektrofotometre.

IZDVAJAMO:

AAS
ICP-OES
ICP-TOFMS
UV/VIS





GBC

ERALY & ASSOCIES

ERALY & ASSOCIES je kompanija specijalizovana za razvijanje i proizvodnju laboratorijskih peći i elementalnih analizatora prvenstveno za određivanje sumpora, azota i hlora u naftnim derivatima, prirodnom gasu, TNG-u, plastici, vodi, organskim materijama itd. Određivanje sadržaja ovih elemenata je neophodno kako u sirovinama tako u gotovim proizvodima.
Tokom 50 godina opsluživanja industrijskih kupaca i istraživačkih laboratorija, ERALY & ASSOCIES je obezbedio razvoj i proizvodnju različitih tipova elementalnih analizatora.

IZDVAJAMO:

ANALIZATOR SUMPORA I AZOTA
ANALIZATOR HALOGENA / HLORA
CEVASTE PEĆI

Eraly

Kalorimetrija, elementarni analizatori, termogravimetrijski analizatori, instrumenti za merenje topljivosti pepela, oprema za uzorakovanje, glavni su segmenti proizvodnje naseg azijskog partnera.

IZDVAJAMO:

AUTOMATSKI KALORIMETAR
AUTOMATSKE ELEMENTALNE ANALIZATORE

CKIC

SFE PROCESS EXTRACTION

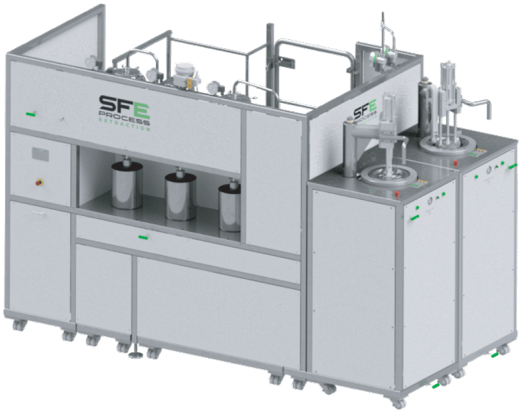
Široka ponuda rešenja za superkritičnu CO2 ekstrakciju. Superkritični CO2 ekstraktori od laboratorijskih do proizvodnih kapaciteta.

Superkritični CO2 se dobija povećanjem pritiska i temperature ugljen-dioksida dok ne postane rastvarač, međustanje između gasa i tečnosti.
Zahvaljujući ovim svojstvima, superkritični CO2 prodire u srce materijala kako bi iz istog izvukao jedinjenja od interesa. Promenom operativnih parametara ekstrakcije, možemo kontrolisati snagu rastvarača CO2 i na taj način ciljati ekstrahovane molekule ili jedinjenja prema njihovoj hemijskoj prirodi.

Superkritični fluidi se koriste kao efikasni rastvarači u procesima kao što su ekstrakcija, impregnacija, formiranje čestica (SAS, PGSS, RESS), formulacija, sterilizacija, oblaganje jedinjenja, ekstrakcija aktivnih sastojaka, čišćenje, hemijske reakcije i druge.

IZDVAJAMO:

SIY- PRENOSIVI CO2 EKSTRAKTOR
SFE LAB LABORATORIJSKI OPSEG - OD 100ML DO 2L
SFE PROD PROIZVODNI OPSEG - OD 2X5L DO 2X100L



SFE PROCESS EXTRACTION


Malvern
Panalytical


HORIBA


LINETRONIC
TECHNOLOGIES


LINSEIS


DISTEK
CREATING A STIR


KNAUER

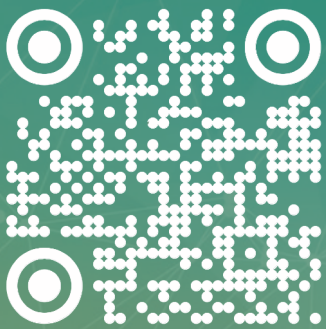

GBC


Eraly


LiliChro


CKiC


SFE
PROCESS
EXTRACTION



KRUG INTERNATIONAL LTD.

Deset avijatičara 2a, 11000 Beorgrad
+381 11 3049-730 +381 11 3049-732 +381 11 3049-736
www.kruginter.com
sales@kruginter.com

WELCOME COCTAIL SPONSORS

SPONZORI KOKTELA DOBRODOŠLICE


KEF
75

D&F TRADING AND CONSULTING

SPONSORS

SPONZORI

ALFATERM

ALFATERM d.o.o. je osnovano 1993. kao specijalizovano preduzeće za termotehnička postrojenja i uređaje površinske zaštite.
Zaposleni u preduzeću imaju tridesetogodišnje iskustvo u razvoju tehnologija i postrojenja površinske zaštite.
Okrenuti smo u smeru pronalaženja kreativnih rešenja i usluga koja su osmišljena da zadovolje veoma različite potrebe naših kupaca.

Ventilacija

- Generatori toplog vazduha i ložišta
- Otprašivanje
- Ventilatori

Plastifikacija metala

- Uređaji za predtretman radnih komada
- Kabine za nanošenje premaza u prahu
- Sušare za vlagu
- Peći za pečenje premaza u prahu

Mokro lakiranje i farbanje

- Kabina za lakiranje sa suvim filterom
- Fini filter
- Zagrejači svežeg vazduha,
- Kolica
- Pomoćna i prateća oprema

Transporteri

Zastupništvo

GRACO
www.graco.com
KEWESTA
www.kewesta.de
Liquid Control
www.liquidcontrol.co.uk

ALFATERM
Njegoševa 6, 32103 Čačak • Srbija
• e-mail: office@alfaterm.rs • www.alfaterm.rs
tel: +381 32 320 645 • fax: +381 32 226 222


INTERNATIONAL SOCIETY OF ELECTROCHEMISTRY
ISE


KANSAI
HELIOS

Institut za preventivu

zaštitu na radu, protivpožarnu zaštitu i razvoj d.o.o.

21000 Novi Sad • Kraljevića Marka 11 • tel/fax: 021 / 420-571, 420-572, 420-573
institut@izp.rs • www.izp.rs

ATC 04-010 АКРЕДИТОВАНО СЕРТИФИКАЦИОНО ТЕЛО SRPS EN 45011:2004

ATC 06-013 АКРЕДИТОВАНА КОНТРОЛНА ОРГАНИЗАЦИЈА SRPS ISO/IEC 17020:2002

ATC 01-069 АКРЕДИТОВАНА ЛАБОРАТОРИЈА ЗА ИСПИТИВАЊЕ SRPS ISO/IEC 17025:2006

- bezbednost i zdravlje na radu
- zaštita od požara i eksplozije
- zaštita životne sredine
- tehnički pregledi objekata
- izrada projektno tehničke dokumentacije
- katodna zaštita
- akreditovana tela
- sertifikacija i ispitivanje opreme u "Ex" izvedbi