

University of Belgrade
Technical Faculty in Bor
Mining and Metallurgy
Institute Bor



56th International October Conference on Mining and Metallurgy **PROCEEDINGS**

Editors:

Ljubiša Balanović

Dejan Tanikić

**22-25 October 2025,
Bor Lake, Serbia**



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Proceedings cover design:

MSc Aleksandar Cvetković,

University of Belgrade - Technical Faculty in Bor

Publisher: University of Belgrade - Technical Faculty in Bor

For the publisher: Dean Prof. dr Dejan Tanikić

Circulation: 200 copies

Publication Place, Year: Bor, 2025

Printed by “*GRAFIKA GALEB DOO*” NIŠ, 2025

CIP - Каталогизација у публикацији Народна библиотека Србије, Београд

622(082)(0.034.2)

669(082)(0.034.2)

INTERNATIONAL October Conference on Mining and Metallurgy (56 ; 2025 ; Bor Lake)

Proceedings [Elektronski izvor] / 56th International October Conference on Mining and Metallurgy - IOC 2025, 22-25 October, 2025, Bor Lake, Serbia ; [organized by] University of Belgrade, Technical Faculty in Bor and Mining and Metallurgy Institute Bor ; editors Ljubiša Balanović, Dejan Tanikić. - Bor : University of Belgrade, Technical Faculty, 2025 (Niš : Grafika Galeb). - 1 USB fleš memorija ; 1 x 1 x 5 cm

Sistemske zahteve: Nisu navedeni. - Nasl. sa naslovne strane dokumenta. - Tiraž 200. - Preface / Ljubiša Balanović. - Bibliografija uz svaki rad.

ISBN 978-86-6305-164-5

a) Рударство -- Зборници b) Металургија -- Зборници

COBISS.SR-ID 177493257

Bor Lake, Serbia, October 22-25, 2025



The conference is financially supported by
The Ministry of Science, Technological
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PREFACE

On behalf of the Organizing Committee, it is a great honor and pleasure to welcome all esteemed participants of the **56th International October Conference on Mining and Metallurgy (IOC 2025)**, scheduled to take place at **Bor Lake, Serbia**, from **October 22nd to 25th, 2025**.

The collaborative efforts of the University of Belgrade – Technical Faculty in Bor and the Mining and Metallurgy Institute Bor have once again brought together academia, industry, and research institutions to organize this year's IOC. Our focus remains firmly set on presenting the latest research achievements and technological advancements in geology, mining, metallurgy, materials science, technology, environmental protection, and other engineering disciplines.

This year's conference program is rich and diverse, featuring **4 plenary lectures, 4 invited lectures, 158 full papers, and 6 abstracts**. The proceedings reflect the contributions of authors from **19 countries**: Austria, Bosnia and Herzegovina, Bulgaria, Canada, China, Croatia, Germany, Hungary, India, Mexico, Montenegro, Poland, Romania, Russia, Serbia, Slovakia, Slovenia, Turkey, and the United Kingdom. Among the submitted papers, eight young researchers under the age of 35 have qualified to participate in the “**MDPI Young Researcher Award**” competition, further emphasizing the conference's commitment to supporting and recognizing excellence among the new generation of scientists and engineers.

We are also delighted to host the **9th International Student Conference on Technical Sciences (ISC 2025)**, running in parallel with IOC 2025. The student conference brings together young researchers from Serbia and the wider region, with **one plenary** and **50 student papers** presented, offering an invaluable opportunity for the next generation of scientists and engineers to share their ideas and discuss the future of their disciplines with experts. The “**Professor Dragana Živković Best Student Paper Award**” will be presented to the most outstanding student contribution based on originality, research quality, and presentation.

The Organizing Committee expresses its deepest gratitude to all who have supported this event. Our General Sponsor is the Ministry of Science, Technological Development, and Innovation of the Republic of Serbia. We are especially grateful to our Platinum Donors, HBIS Serbia and Serbia Zijin Mining, as well as our Gold Sponsor, DPM Metals Inc., and our Gold Donors, Copper Mill Sevojno and Serbia Zijin Copper Bor. This year, the conference is also supported by the Silver Donor, “MC LABOR” d.o.o. Beograd.

We proudly host a diverse exhibition, featuring Indemak, Labtim SE d.o.o., MERIS d.o.o., Krug International LTD, Altium International d.o.o., Metalurg Foundry Ltd., Fugro Germany Land GmbH, Analysis d.o.o., Lola institut, Tescan and Mikrolux d.o.o., Trokutest Serbia, Novos d.o.o., Changsha Rui Rui Technology Co., Ltd., MDPI and the Winery of Bukovo Monastery. The official opening of the conference has been supported by Epiroc Srbija a.d.. Finally, we warmly acknowledge our Friends of the Conference: Messer Tehnogas AD Belgrade, the China-Serbia Joint Laboratory on Green Steel Manufacturing, and the Foundation B.Sc. Boško Injac.

We sincerely thank all authors, committees, reviewers, speakers, and chairpersons for their invaluable contributions to shaping IOC 2025. We are confident that the conference will once again serve as a alive platform for scientific exchange, professional networking, and the promotion of sustainable development in mining, metallurgy, and related fields.

On behalf of the 56th IOC Organizing Committee,
Prof. dr Ljubiša Balanović

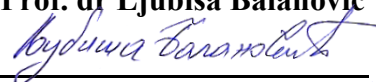


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ELECTROCHEMICAL BEHAVIOR OF COPPER IN CHLORIDE MEDIUM IN THE PRESENCE OF PINE CONE MACERATE

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Abstract

The article presents the results of the study of the electrochemical behavior of copper during oxidation in a 0.5 mol/dm³ NaCl solution in the absence and presence of pine cone macerate of different concentrations. The electrochemical behavior of copper was investigated using the cyclic voltammetry method and the potentiostatic method. The results of cyclic voltammetry show that three current peaks appear on the anodic polarization curves, which correspond to the formation of copper chloride and copper oxide. Potentiostatic polarization was performed at 0.5 mV vs. SCE for 100 s and at 25°C. Potentiostatic curves show that the steady-state currents decrease with increasing concentration of macerate in the electrolyte. Microscopic images confirm that a protective layer has formed on the copper surface in the presence of the pine cone macerate, which prevents the corrosion process.

Keywords: electrochemical behavior, copper, chloride medium, pine cone macerate

1. INTRODUCTION

Corrosion of copper and its alloys is a major problem because it causes considerable material and financial losses. To protect against corrosion, it is important to investigate the effect of various potential inhibitors in different environments. So far, a large number of potential inhibitors have been investigated. Research should be focussed on the application of ecological - "green" inhibitors, with the main criterion for application being their ecological compatibility. Research into plant extracts has recently been of great interest when it comes to corrosion inhibitors [1,2]. They are also natural antioxidants that are cheap and have no negative impact on the environment. The inhibitory effect of some plant extracts is achieved by the presence of tannins in their composition. In perennial herbaceous plants, the underground organs (rhizomes and roots) are richest in tannins, while in woody plants the bark of roots, stems and thicker branches, leaves, fruits, etc. are richest in tannins [3].

This paper presents the results of the investigation of the influence of pine cone macerate on the corrosion behaviour of copper in 0.5 mol/dm³ NaCl.

2. EXPERIMENTAL

To prepare a solution of 0.5 mol/dm³ NaCl, NaCl produced by d.d. "Zorka Pharma" Šabac was used. The solution was prepared with chemicals of p.a purity and distilled water. The working solutions were prepared by pouring 10, 20, 30 and 40 mL of pine cone macerate (Pinophyta) into volumetric flasks of 100 mL each and then adding a solution of 0.5 mol/dm³ NaCl, always

maintaining the concentration of sodium chloride in the solution. The macerate of pine cones was prepared as follows: first, 1000 mL of distilled water was heated up to 60 °C and then 100 g of crushed sporophylls of pine cones were added. The process to obtain the macerate takes 4 hours, mixing with a magnetic stirrer at 400 min⁻¹. After 4 hours, the resulting macerate is filtered in a Bichner apparatus and stored in a refrigerator.

The experiments were carried out using a system consisting of an electrochemical cell with three electrodes (working, reference and auxiliary electrode), hardware (PC, Burr-Brown PCI-20428W, AD/DA converter and an analogue interface developed at the Faculty of Engineering in Bor) [4]. The study of the electrochemical behaviour of copper in 0.5 mol/dm³ NaCl solution in the absence and presence of pinecone macerate was carried out by recording the anodic polarization curves. The curves were recorded in the potential range from -0.4 V vs. SCE to 1 V vs. SCE with a scan rate of 20 mV/s. The potentiostatic curves were recorded at 0.5 V vs. SCE for 100 s. Optical microscopy was used to characterize the electrode surface after potentiostatic oxidation.

3. RESULTS AND DISCUSSION

Figure 1 shows the anodic polarization curves for pure copper in 0.5 mol/dm³ NaCl solution with and without pine cone macerate.

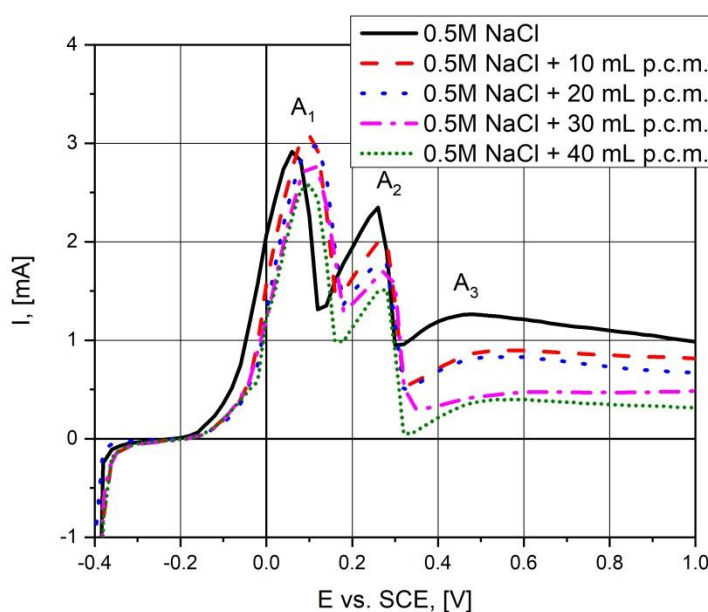


Figure 1. Anodic polarization curves for copper with a scan rate of 20 mV/s in 0.5 mol/dm³ NaCl with and without the addition of pine cone macerate (p.c.m.- pine cone macerate)

Three current peaks corresponding to the formation of chloride (current peaks A₁ and A₂) and copper oxide (current peak A₃) appear on the anodic polarization curve obtained in 0.5 mol/dm³ NaCl [5,6]. With the addition of 10 mL and 20 mL of pine cone macerate, the current strength values for current peak A₁ are higher compared to the current strength value without the addition of pine cone macerate, while the current strength values with the addition of 30 mL and 40 mL of pine cone macerate are lower compared to the current strength value without the addition of macerate. In the area of the potential where the current peaks A₂ and A₃ occur, the values of the current strength of the current peaks in the presence of pine cone macerate are lower than the value of the current strength without the addition of pine cone macerate at all macerate concentrations. From the polarization curves obtained, it can be concluded that pine cone macerate slows down

the process of copper chloride and oxide formation on the copper surface and that pine cone macerate acts as an anodic inhibitor of copper corrosion in 0.5 mol/dm³ NaCl.

Figure 2 shows the potentiostatic curves after potentiostatic treatment of copper for 100 s in 0.5 mol/dm³ NaCl solution without and with pine cone macerate.

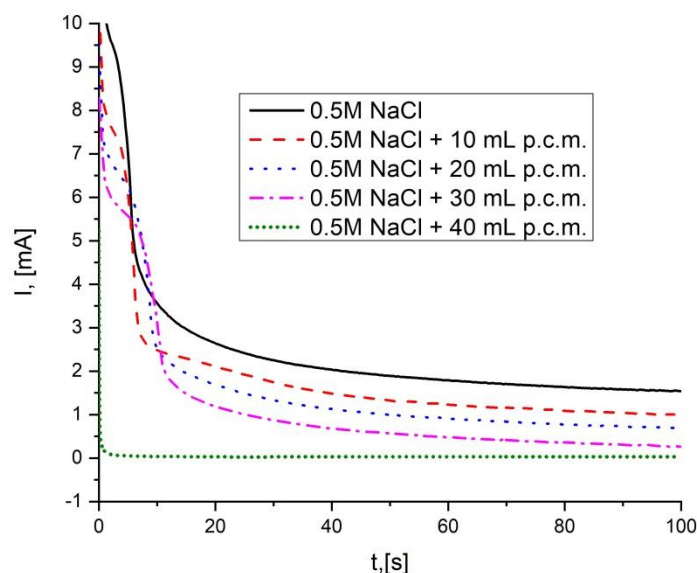


Figure 2. Potentiostatic curves for copper in 0.5 mol/dm³ NaCl without and with the addition of pine cone macerate (p.c.m.- pine cone macerate) at 0.5 V vs. SCE

The potentiostatic curve obtained for copper with the addition of 10 mL of pine cone macerate drops sharply in the first 7 seconds, then the curve decreases monotonically until about 90 seconds when it stabilizes and the value of the steady-state current is 1 mA. The potentiostatic curve obtained for copper with the addition of 20 mL of pine cone macerate drops sharply in the first 10 seconds and then continues to decrease slowly until it stabilizes after about 80 seconds and the value of the steady-state current is 1.6 mA. The potentiostatic curve obtained for copper with the addition of 30 mL of macerate drops sharply in the first 10 seconds, then continues to decrease slightly and stabilizes at around 90 seconds, with the value of the steady-state current being 0.3 mA. When 40 mL of pine cone macerate is added, stabilization occurs in the first few seconds and the value of the steady-state current is 0 mA. This means that the pine cone macerate protects the copper surface well against corrosion. Figure 3a shows a photomicrograph of untreated copper. Figures 3b, 3c, 3d, 3e and 3f show microphotographs of the copper surface after potentiostatic treatment in 0.5 mol/dm³ NaCl without and with the addition of pine cone macerate.

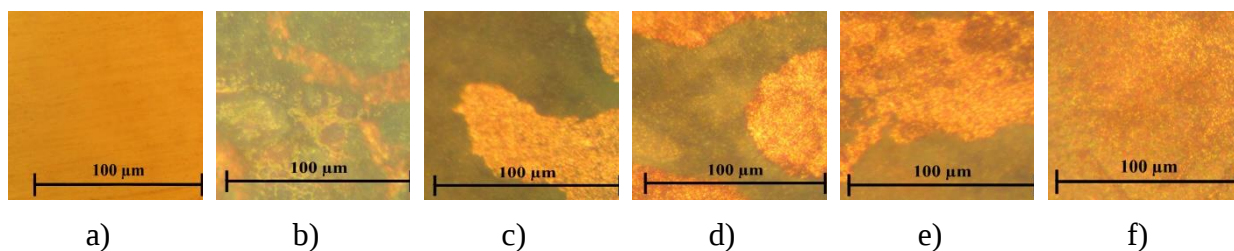


Figure 3. Microphotographs of the copper surface after potentiostatic treatment on the potential of 0 V vs. SCE during 100 s: a) untreated surface; b) in 0,5mol/dm³ NaCl; c) in 0,5mol/dm³ NaCl + 10 mL pine cone macerate; d) in 0,5mol/dm³ NaCl + 20 mL pine cone macerate; e) in 0,5mol/dm³ NaCl + 30 mL pine cone macerate; f) in 0,5mol/dm³ NaCl + 40 mL pine cone macerate

4. CONCLUSION

Increasing concern for the protection of the environment has led to stricter regulations on the use of chemicals that can have a harmful effect on the environment. This has resulted in the use of a number of very effective inhibitors being reduced or discontinued.

Based on the experiments carried out, the following conclusions can be drawn:

- When investigating the electrochemical behavior of copper using the cyclic voltammetry method in 0.5 mol/dm³ NaCl, it was found that three current peaks appear on the anodic polarization curve. The current peaks A₁ and A₂ correspond to the formation of copper chloride, while the current peak A₃ corresponds to the formation of copper oxide on the surface. In the presence of pine cone macerate, the inhibitory effect of the macerate is achieved in the area of potential A₁ with the addition of more than 20 mL, while in the area of potential A₂ and A₃ the pine cone macerate has an inhibitory effect at all investigated concentrations of pine cone macerate.

- The results of the potentiostatic measurement show that stabilization is achieved more quickly in the presence of pine cone macerate. The values of the steady-state current in the 0.5 mol/dm³ NaCl solution in the presence of macerate are lower than the value of the steady-state current without the presence of macerate. This indicates that a protective film forms on the copper surface in the presence of the macerate, which slows down the copper oxidation process.

- Photomicrographs after potentiostatic treatment of copper in a 0.5 mol/dm³ NaCl solution clearly show the presence of a green phase, representing copper chloride, and a black phase, representing copper oxide. When pine cone macerate is added, the photomicrographs show green and black phases on a smaller scale. This indicates that pine cone macerate acts as a copper corrosion inhibitor.

ACKNOWLEDGEMENTS

The research presented in this paper was done with the financial support of the Ministry of Education, Science and Technological Development of the Republic of Serbia, within the funding of the scientific research work at the University of Belgrade, Technical Faculty in Bor, according to the contract with registration no. 451-03-137/2025-03/200131.

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