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Editors:
Ljubiša Balanović
Dejan Tanikić

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PREFACE

On behalf of the Organizing Committee, it is a great honor and pleasure to welcome all esteemed participants of the 54th International October Conference on Mining and Metallurgy (IOC 2023), scheduled to take place at the picturesque Bor Lake, Serbia, from October18th to 21st 2023.

The collaborative efforts of the University of Belgrade, the Technical Faculty in Bor, and the Mining and Metallurgy Institute Bor have meticulously organized this year's IOC. Our focus remains unwavering on showcasing the latest research findings and advancements in geology, mining, metallurgy, materials science, technology, environmental protection, and other engineering disciplines. Our primary objective is to foster a dynamic environment where academics, researchers, and industry professionals can come together to share their knowledge, experiences, and innovative ideas while exploring opportunities for collaborative research endeavors.

Our conference agenda is rich and diverse, encompassing plenary sessions, engaging invited lectures, technical presentations, enlightening oral and poster sessions, informative technical tours, a diverse exhibition, and memorable social gatherings. At the heart of this event lies our strong commitment to sustainable development within the mining and metallurgy sector. We are dedicated to exploring ecologically conscious methodologies, responsible resource extraction practices, and cutting-edge technologies that reduce the industry's environmental impact and enhance the well-being of local communities.

The conference proceedings comprise 129 papers authored by individuals from universities, research institutes, and industries in 22 countries. We are proud to welcome participants from Bosnia and Herzegovina, Bulgaria, Canada, China, Croatia, Germany, Greece, India, Iran, Kazakhstan, Libya, North Macedonia, Montenegro, Morocco, Romania, Russia, Slovakia, South Africa, Spain, Turkey, United States, and, of course, Serbia.

We are excited to host the 8th International Student Conference on Technical Sciences (ISC 2023) as part of IOC 2023. This event offers students from Serbia and the wider region a unique chance to showcase their research and discuss the future of their fields with experts.

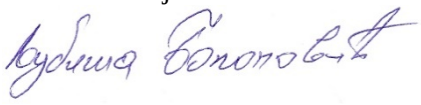
We sincerely thank the Ministry of Science, Technological Development, and Innovation of the Republic of Serbia for their generous financial support. In addition, we express our profound gratitude to all our sponsors, exhibitors, and friends of the Conference for their contributions and unwavering support for playing a pivotal role in ensuring the success of IOC 2023.

We would like to express our heartfelt thanks to all authors, committees, reviewers, speakers, and chairpersons for their invaluable contributions in shaping IOC 2023.

We look forward to welcoming you to the 55th International October Conference on Mining and Metallurgy (IOC 2024), which will be held in October 2024.

On behalf of the 54th IOC Organizing Committee,

Prof. dr Ljubiša Balanović



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ELECTROCHEMICAL BEHAVIOR OF COPPER IN CHLORIDE MEDIUM IN THE PRESENCE OF NETTLE EXTRACT

Vesna Grekulović[1], Aleksandra Mitovski[2], Milica Zdravković[1], Nada Štrbac[1], Milan Gorgievski[1], Milovan Vuković[1], Miljan Marković[1]

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Abstract

The use of plant extracts to inhibit copper corrosion is the subject of numerous scientific studies. This paper presents the results of research the electrochemical behavior of copper during oxidation in a 0.5 mol/dm^3 NaCl solution in the absence and presence of nettle extract (NE) in different concentrations. The electrochemical behavior of copper was investigated using the cyclic voltammetry and the potentiostatic method. The results of cyclic voltammetry showed 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 mV vs. SCE during 100 s at 25 ^{o}C. The potentiostatic curves indicate that the stationary currents decrease with increasing extract concentration in the electrolyte. Microphotographs confirmed that in the presence of NE, a protective layer was formed on the copper surface, which prevents the corrosion process.

Keywords: *copper, electrochemical behavior, chloride medium, nettle extract*

1. INTRODUCTION

Copper has been for decades one of the most strategically important metals in the industry, because of its physical and chemical properties, which enable its wide range usage in numerous products of modern society. Copper corrosion and its inhibition in various environments are the subject of numerous scientific investigations [1-3]. Inhibitors are substances added in different concentrations to a given solution containing aggressive ions. They can be of the organic or inorganic origin. However, many inhibitors are toxic. Plant extracts as potential environmental corrosion inhibitors have become the subject of numerous scientific investigations in the last few years. Various plant parts can be extracted and used as metal corrosion inhibitors [3].

This paper presents the results of investigation the addition of nettle extract (in following text: NE) on the copper corrosion behavior in 0.5 mol/dm^3 NaCl solution.

2. EXPERIMENTAL

The experiments were carried out in a system consisting of an electrochemical cell and a hardware interface for computerized control and data acquisition. In a standard three-electrode electrochemical cell, the working electrode was made of copper, whose potential was controlled against a reference saturated calomel electrode (SCE). Platinum foil was used as a counter electrode. The computerized control (National Instruments card, NI-6251) and data acquisition software (LabVIEW 8.2 platform), fully developed at the Technical Faculty in Bor [4], were used to run the electrochemical experiments.

Investigation of the copper electrochemical behavior in 0.5 mol/dm^3 NaCl solution in the absence and the presence of NE was performed by recording the anodic polarization curves. The curves were recorded in the potential range of -0.4 V vs. SCE up to 1 V vs. SCE with a scan rate of 20

mV/s. The potentiostatic curves were recorded at 0 V vs. SCE for 100 s. Optical microscopy was used for the electrode surface characterization after potentiostatic oxidation.

The substances used for the preparation of the working solutions were NaCl (p.a purity), manufactured by d.d. "Zorka Pharma" Šabac and fresh nettles harvested in the vicinity of Bor. The NE was prepared as follows: 100 g of nettle was chopped and placed in 200 mL of 96% ethanol. After standing in ethanol solution for one month, the solution was filtered and the obtained nettle extract was stored in the refrigerator.

3. RESULTS AND DISCUSSION

Figure 1 shows the anodic polarization curves recorded for copper in 0.5 mol/dm^3 NaCl without and with NE of different volumes.

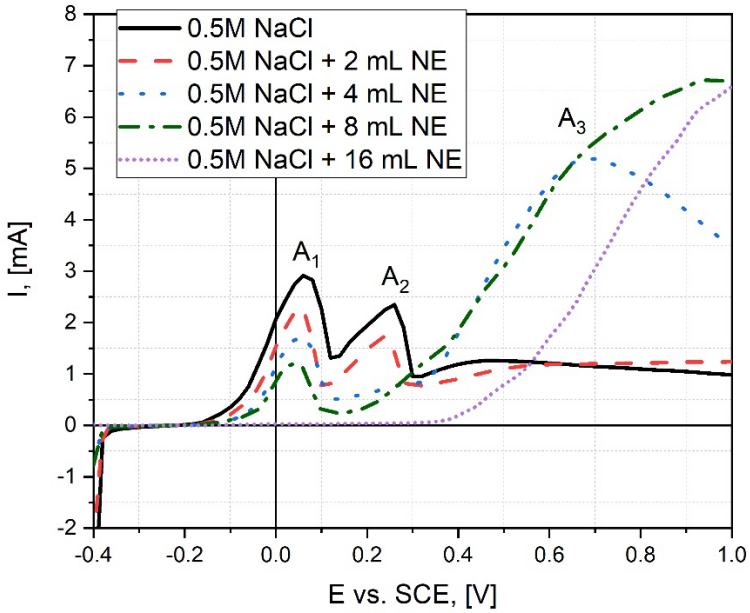


Figure 1 - Anodic polarization curves for copper with a scan rate of 20 mV/s in 0.5 mol/dm^3 NaCl with and without the addition of NE

On the anodic polarization curve, obtained for 0.5 mol/dm^3 NaCl, three current peaks appeared. They correspond to the formation of copper chloride and copper oxide [5, 6]. Comparing the anodic polarization curves for copper obtained in the presence of NE with the anodic polarization curve without the NE, it can be observed that the current values for the current peaks A1 and A2 in the presence of 2 mL, 4 mL and 8 mL NE are lower in relation to the current values without NE. The best inhibitory effect is achieved with the addition of 16 mL NE, as shown by the current values of the current peaks A1 and A2, which are approximately equal to zero. With the addition of 2 mL NE in the potential area where the current peak A3 appears, the current values are approximately equal to the current values without the addition. With the addition of 4 mL NE, a clearly defined current peak A3 appears, which represents the formation of copper oxide. In the presence of 8 mL and 16 mL NE, there is a sudden current value increase in the potential area where the current peak A3 appears, which indicates that there is a separation of oxygen and the formation of a certain amount of copper oxide.

Figure 2 shows the potentiostatic curves after the potentiostatic treatment of copper during 100 s in 0.5 mol/dm^3 NaCl without and with the addition of NE.

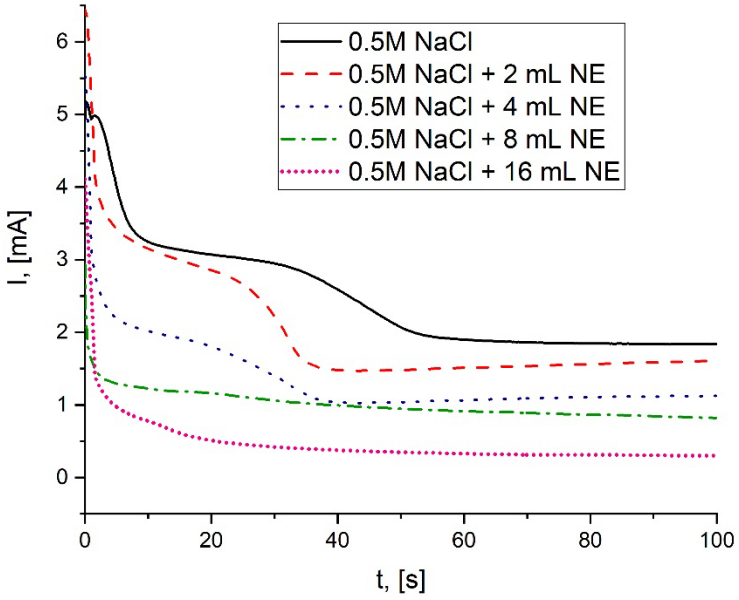
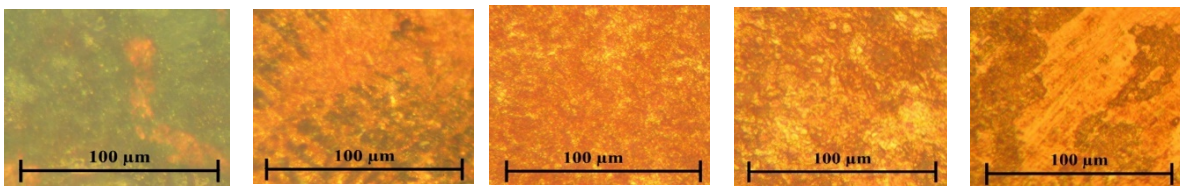


Figure 2 - Potentiostatic curves for copper in 0.5 mol/dm^3 NaCl without and with the addition of NE at 0 V vs. SCE

The current strength for copper in 0.5 mol/dm^3 NaCl without the addition of NE drops sharply in the first 8 s, then slowly decreases until about 55 s, after which it stabilizes. The value of the stationary current strength amounts to 1.838 mA. With the addition of 2 mL and 4 mL NE, there is a sudden drop in the current strength in the first 4 s, then it slowly decreases until about 40 s, after which there is a slight increase and stabilization. The value of the stationary current with the addition of 2 mL NE is 0.818 mA, and with the addition of 4 mL NE is 0.565 mA. The potentiostatic curve obtained for copper with the addition of 8 mL NE drops sharply in the first few seconds, then continues to decrease slightly and stabilizes at about 90 seconds, with the value of the stationary current strength being 0.536 mA. With the addition of 16 mL NE, the current drops sharply in the first seconds, after which it slowly decreases until about 60 s, and then it stabilizes and reaches the stationary current value of 0.499 mA. Based on the obtained results, it can be concluded that with an increase in the volume of NE, the stabilization of the current is achieved faster and the values of the stationary current are lower, which indicates that a protective layer is formed on the copper surface.

Analysis of the copper surface by optical microscopy was performed after the potentiostatic treatment of copper in the presence and in the absence of NE.

Figures 3a, 3b, 3c, 3d and 3e show microphotographs of the copper surface after potentiostatic treatment in a solution of 0.5 mol/dm^3 NaCl without and with the addition of NE. Figure 3a shows a microphotograph of the copper surface after potentiostatic treatment in 0.5 mol/dm^3 NaCl, where it is clearly seen that the surface is significantly damaged and that copper chlorides and copper oxide were formed on the surface during the oxidation process. In the presence of NE, a protective film is formed, which protects the copper surface from corrosion. As the volume of NE increases, the copper surface is less damaged and there is less presence of chlorides and oxides. With the addition of 16 mL NE only a black phase is present on the copper surface. This confirms the results obtained by the method of cyclic voltammetry, that the NE prevents the formation of copper chloride, and stimulates the process of copper oxide formation.



a) b) c) d) e)

Figure 3 - Microphotographs of the copper surface after potentiostatic treatment on the potential of 0 V vs. SCE during 100 s: a) in 0,5mol/dm^3 NaCl; b) in 0,5mol/dm^3 NaCl + 2 mL NE; c) in 0,5mol/dm^3 NaCl + 4 mL NE; d) in 0,5mol/dm^3 NaCl + 8 mL NE; e) in 0,5mol/dm^3 NaCl + 16 mL NE

4. CONCLUSION

Based on the performed experiments, the following conclusions can be drawn:

Investigation of the electrochemical behavior of copper using the cyclic voltammetry method in 0.5 mol/dm^3 NaCl, three current peaks appeared on the anodic polarization curve, which corresponds to the formation of copper chloride and oxide. In the presence of NE, the inhibitory effect is achieved in the area of copper chloride formation potential at all tested concentrations of NE, while in the area of copper oxide formation potential, NE acts as a corrosion activator. Potentiostatic tests show that the stationary current strength in the presence of nettle extract is significantly lower compared to the stationary current strength in 0.5 mol/dm^3 NaCl. Lower stationary current values in the presence of the extract indicate that a protective layer was formed on the copper surface, which prevents the corrosion process. With the increase of NE concentration, the values of the stationary current are lower. After the potentiostatic treatment of copper in 0.5 mol/dm^3 NaCl solution, the microphotograph of the copper surface shows that copper chloride and oxide are formed and that the copper surface is significantly damaged. In the presence of NE, damage on the copper surface is less noticeable and the copper chloride and oxide amount are decreased. As the concentration of the extract increases, the damage is less noticeable, which indicates that the NE provides good protection of copper against corrosion.

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