



University of Belgrade, Technical Faculty in Bor
29th International Conference Ecological Truth
& Environmental Research



EcoTER'22

Proceedings



Editor

Prof. Dr Snežana Šerbula

21-24 June 2022, Hotel Sunce, Sokobanja, Serbia



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PREFACE

In today's world, the environment has been endangered by the use of outdated technology, fossil fuels and environmental law violations. Therefore, environmental and many other scientists all over the world have been concerned about finding sustainable technology in resolving these issues. That is why environmental research and ecological truth are at the focus of the 29th International Conference Ecological Truth & Environmental Research 2022 (EcoTER'22), which will be held in Sokobanja, Serbia, 21–24 June 2022. On behalf of the Organizing Committee, it is a great honor and pleasure to wish all the participants a warm welcome to the Conference.

We hope to convey the message of the conference, which is that a transformation of attitudes and behavior would bring the necessary changes. This is also an opportunity for the participants who are experts in this field to exchange their experiences, expertise and ideas, and also to consider the possibilities for their collaborative research.

The 29th International Conference Ecological Truth & Environmental Research 2022 is organized by the University of Belgrade, Technical Faculty in Bor, and co-organized by the University of Banja Luka, Faculty of Technology, the University of Montenegro, Faculty of Metallurgy and Technology – Podgorica, the University of Zagreb, Faculty of Metallurgy – Sisak, the University of Pristina, Faculty of Technical Sciences – Kosovska Mitrovica and the Association of Young Researchers, Bor.

These proceedings include 85 papers from the authors coming from the universities, research institutes and industries in 6 countries: Bulgaria, Italia, Albania, Bosnia and Herzegovina, Montenegro and Serbia.

As a part of this year's conference, the 4th Student section – EcoTERS'22 is being held. We appreciate the contribution of the students and their mentors who have also participated in the Conference.

Financial assistance provided by the Ministry of Education, Science and Technological Development of the Republic of Serbia is gratefully acknowledged by the Organizing Committee of the EcoTER'22 conference.

The support of the Platinum donor and their willingness and ability to cooperate have been of great importance for the success of EcoTER'22. The Organizing Committee would like to extend their appreciation and gratitude to the Platinum donor of the Conference for their donation and support.

We appreciate the effort of all the authors who have contributed to these Proceedings. We would also like to express our gratitude to the members of the scientific and organizing committees, reviewers, speakers, chairpersons and all the Conference participants for their support to EcoTER'22. Sincere thanks go to all the people who have contributed to the successful organization of EcoTER'22.

Prof. Snežana Šerbula,

President of the Organizing Committee

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CAFFEINE AS A GREEN CORROSION INHIBITOR FOR COPPER IN SYNTHETIC BLOOD PLASMA SOLUTION

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Abstract

Caffeine as a green inhibitor for copper in synthetic blood plasma solution was investigated. Potentiodynamic measurements and open circuit potential measurements were used to study caffeine as a corrosion inhibitor of copper. Gathered results point out that caffeine has a good inhibitory characteristic. Adsorption of caffeine on the copper surface, which is important in the inhibition mechanism, follows Langmuir adsorption mechanism.

Keywords: caffeine, blood plasma solution, copper, corrosion inhibition

INTRODUCTION

Copper is relatively noble metal that does not corrode readily unless some oxidizing agent or oxygen is present. That is the reason for its wide use in the manufacturing of electronics, thermal exchangers, and electrical conductors [1]. To protect metals and alloys surfaces from corrosion caused by aggressive ions suitable inhibitor can be applied.

In order to protect the metal surface in aggressive media, various organic substances are used which block reactive sites on copper surface [2]. Literature data showed that most effective inhibitors of corrosion are the organic molecules consisting of a π -system and/or containing atoms such as nitrogen, oxygen or sulphur in their molecule structures [3–5]. The inhibition mechanism can take place through two processes either by forming a protective tin film via inhibitor adsorption or by forming a precipitate on the surface of the electrode [6].

This paper deals with corrosion inhibitory effect of different concentrations of caffeine on copper electrode in blood plasma solution.

MATERIALS AND METHODS

The solutions used were made from chemicals p.a. cleanliness. Synthetic blood plasma solution (BM-3) was used as the base during the study, while caffeine played the role of inhibitor (1,3,7-trimethylxanthine) of the following concentrations $1.0 \cdot 10^{-2}$ M, $5.0 \cdot 10^{-3}$ M, $1.0 \cdot 10^{-3}$ M and $5.0 \cdot 10^{-4}$ M.

By diluting the caffeine solution with a concentration of $1.0 \cdot 10^{-2}$ M by adding the BM-3 stock solution, a series of lower concentration inhibitor solutions was obtained. The composition of the artificial blood plasma solution (BM-3) is shown in Table 1.

Table 1 Compounds that are part of the BM-3 solution, shown in grams

Compound	Mass (g)
NaCl	4.7865
KCl	0.3975
MgCl ₂ ·6H ₂ O	0.1655
CaCl ₂ ·2H ₂ O	0.2646
NaHCO ₃	3.7005
NaH ₂ PO ₄ ·H ₂ O	0.1250

Electrochemical measurements were performed in a three-electrode system. All electrochemical tests were conducted on potentiostat (IVIUMSTAT XRe, IVIUM Technologies) with the appropriate software. Electrochemical methods applied for investigation were: open circuit potential (OCP), linear potentiodynamic polarization (LV) and cyclic potentiodynamic voltammetry (CV). All measurements were performed at room temperature.

The open circuit potential was determined in 30 minutes, after which measurement of linear voltammetry was continued from the value of the open circuit potential to $-0.300 V_{SCE}$ while in the cathodic direction and up to $0.300 V$ in the anodic direction. The rate of potential change in LV was 1 mV/s . In cyclic voltammetry, the polarization curves were recorded in the potential interval of $-1.000 V_{SCE}$ to $1.000 V_{SCE}$. These measurements were performed at a scan rate 10 mV/s . The potential is expressed in relation to the saturated calomel electrode.

RESULTS AND DISCUSSION

Open circuit potential

Open circuit potential (OCP) was determined prior to the potentiodynamic polarization of copper electrode. From Figure 1 it is obvious that the addition of caffeine leads to the potential shift towards more positive values of potential and this is attributed to the improved corrosion resistance because of adsorption and formation of protective layer on the copper electrode surface [7].

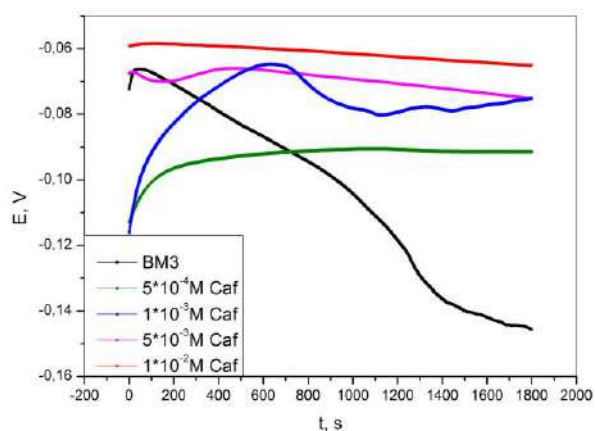


Figure 1 The open circuit potential of copper electrode in BM-3 solution without and with the addition of different concentrations of caffeine

Since the shifted values of the open circuit potential are shifted less than 85 mV, it can be concluded that caffeine as copper corrosion inhibitor can be considered as mixed-type inhibitor [8].

The cyclic voltammetry measurements

In order to test the behaviour of copper in solution of the artificial blood plasma with and without the presence of caffeine, voltammograms were recorded and presented in Figure 2. Results indicated that the presence of different concentrations of the used inhibitor has the effect of reducing the current density that is particularly pronounced at higher concentrations, which can be explained by the formation of protective film on the copper surface [2]. Figure 2 also showed that in the positive sweep, pitting corrosion occurs. Literature data indicate that pitting corrosion occurs when there is a sudden increase in current density and when the reverse current density is greater in the reverse sweep than in the positive sweep in the anodic region [9].

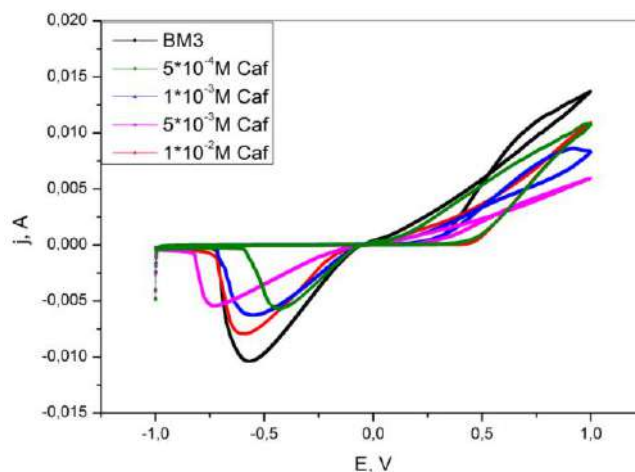


Figure 2 Cyclic voltammetry curves recorded for copper in artificial blood plasma without and with the addition of caffeine

Linear potentiodynamic polarization

Figure 3 presents the potentiodynamic polarization curves obtained after the determination of OCP. Potentiodynamic polarization curves for copper were recorded in blank BM-3 solution and in presence of caffeine as corrosion inhibitor.

Applied caffeine as a corrosion inhibitor leads to decrease of the current density value suggesting that caffeine is adsorbed on the copper surface and hinders anodic and cathodic reactions. All electrochemical corrosion parameters were calculated by potentiodynamic polarization curves, which are shown in Figure 3.

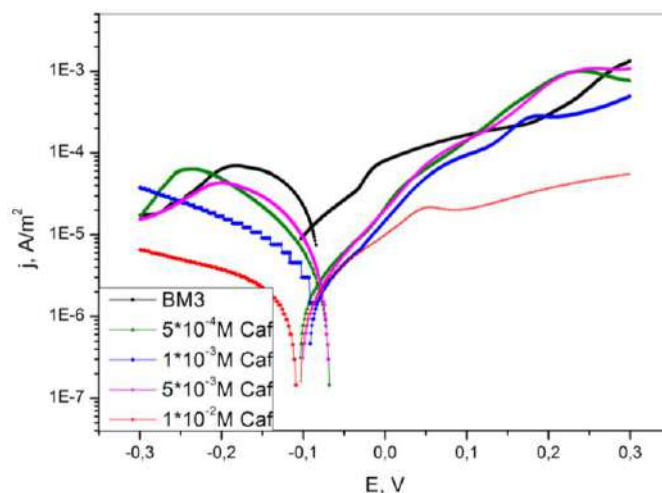


Figure 3 Potentiodynamic polarization curves of copper in BM-3 solution without and with the addition of different concentrations of caffeine

Inhibition efficiency was calculated from the linear voltammograms according to the following equation:

$$IE = ((j_{corr} - j_{inh})/j_{corr}) \cdot 100 [\%] \quad (1)$$

where j_{corr} and j_{inh} are corrosion current densities for basic BM-3 solution and with the addition of caffeine.

Table 2 Electrochemical parameters and inhibition efficiency of copper corrosion in BM-3 solution without and with the addition of different concentrations of caffeine

Solution	E_{corr} (V)	$j_{corr} \cdot 10^6$ (A)	IE (%)
BM-3	-0.0898	23,30	/
Caffeine $5 \cdot 10^{-4}$	-0.0775	3.991	82.87
Caffeine $1 \cdot 10^{-3}$	-0.0816	3.701	84.12
Caffeine $5 \cdot 10^{-3}$	-0.0807	3.578	84.64
Caffeine $1 \cdot 10^{-2}$	-0.0848	2.429	96.64

The adsorption mechanism-the adsorption isotherm

The adsorption mechanism is investigated by application of Langmuir adsorption isotherm. The adsorption of the inhibitor on the copper electrode surface could be observed as the adsorption of caffeine at the copper solution interface and substitution process between the organic compound from the aqueous medium and the water molecules associated with the metal surface:



where “x” is the number of water molecules replaced by the adsorption of one caffeine molecule [10].

Gibbs free energy of adsorption was calculated according to the equation:

$$-\Delta G = [\ln K_{ads} - \ln(1/55.55)]RT \quad (3)$$

where R stands for the universal gas constant (J/Kmol) and T is the thermodynamic temperature (295 K).

The value of calculated Gibbs free energy of caffeine adsorption on copper electrode surface was -31.80 kJ/mol, which indicates strong adsorption of caffeine on copper surface.

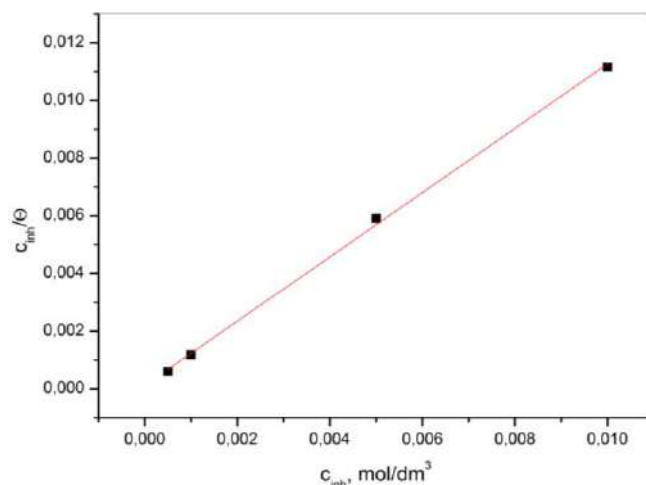


Figure 4 Langmuir adsorption isotherm of caffeine on the copper surface

CONCLUSION

According to the results caffeine can be applied as copper corrosion inhibitor taking into account value of inhibition efficiency when highest concentration of caffeine was applied. The potentiodynamic polarization measurements lead to conclusion that this organic molecule act as a mixed type of inhibitor. The adsorption of caffeine had been found to be obeying Langmuir adsorption isotherm. The negative value of Gibbs free energy points to fast and spontaneous adsorption. This research reveals that caffeine is environmentally friendly and effective inhibitor.

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