Thangarajan Umamathi[1], Venkatachalam Prathipa[2], Arockiam Roslin[3], Arockiaraj Little Jewelcy[3], Micheal Velankanni Jeevithe Clara[3], Nilavan Anitha[3], Mohamed Ibrahim Nasrin Sahana[3], Susai Rajendran[3,4,] Arjunan Krishnaveni[5]

[1]Department of Chemistry, Sri Meenakshi Government Arts College for Women(A), Madurai, India; [2]Department of Chemistry, PSNA College of Engineering and Technology, Dindigul, Tamil Nadu, India; [3]Corrosion Research Centre, Department of Chemistry, St Antony's College of Arts and Sciences for Women, Dindigul, Tamil Nadu, India (Affiliated to Mother Teresa Women's University, Kodaikanal),Tamil Nadu, India; [4]Centre for Nanoscience and Technology, Pondicherry University, Chinna Kalapet, Kalapet, Puducherry, India; [5]PG Department of Chemistry, Yadava College, Natham Road, Tiruppalai, Madurai, Tamil Nadu, India

Scientific paper
ISSN 0351-9465, E-ISSN 2466-2585
https://doi.org/10.10.62638/ZasMat1077

Zastita Materijala 65 (4)
765 - 777 (2024)

Influence of sodium chloride on corrosion resistanceof ever silver vessels in the presence of curd rice

ABSTRACT

The present work is undertaken to investigate the corrosion resistance of ever silver in the presenceof water, water+curd system, water+curd+rice system, water+curd+rice+Salt system. The corrosionresistance has been evaluated by AC impedance spectra . AC impedance spectra have been em- ployed to investigate the corrosion resistance of ever silver electrode when it is immersed in various test solutions like water, curd, curd rice recipe, curd rice recipe with salt (sodium chloride 500 ppm).The corrosion resistance of ever silver electrode when it is immersed in various test solutions like wa- ter, water+curd, water+curd+rice and water+curd+rice+salt have been evaluated by AC impedance spectroscopy.If a protective film is formed, the charge transfer resistance increases, impedance value increases, phase angle value increases and double layer capacitance (C_{dl}) value decreases.When Ever silver electrode is immersed in water + curd rice system + 500ppmsodium chloride system, the corrosion resistance of ever silver electrode decreases. This is due to the presence of chloride ion introduced into the curd rice system. It implies that when curd rice is packed in vessels made of eversilver, we should avoid adding salt to the curd rice. It is better to keep the salt and curd rice separately.It is to be noted that this corrosion resistance is better than the corrosion resistance in water alone.

The corrosion resistance decreases in the following order:

Water + Curd + Rice system > Water + Curd + Rice + Salt system (sodium chloride 500ppm) > Wa-ter+Curd system > Water

Keywords: *corrosion resistance, ever silver, curd rice, sodium chloride, electrochemical studies*

1. INTRODUCTION

Corrosion of food cans is influenced by various factors. They are content of certain compounds in corrosive food products such as sulfur compounds, chloride, nitrates, etc., which are derived from canned materials or from additive compounds; acid-ity or pH of food products.

For corrosion protection of metal cans used as food and beverage packag- ing, coatings based on epoxy phenolics and epoxy esters are the most common.Plastic coating offers several benefits to metal objects. It acts as a barri- er against moisture, preventing rust and corrosion. It also provides insulation, electrical resistance, and impact resistance, enhancing the durability and lifespan of the metal. Several research works have been published dealing with alloys and metals used in food package process and the corrosion behav- ior of these materials [1-10]. The main findings are summarized in Table 1.

*Corresponding author: Susai Rajendran
E-mail: susairajendran@gmail.com
Paper received: 15.05.2024.
Paper accepted: 05. 06. 2024.
Papir is available on the website: www.idk.org.rs/journal

Table 1. Corrosion behavior of metals and alloys used in food packaging processes

SNo/ Ref	Title	Methods employed and findings
1	Electrochemical and AFMstudy of inhibitory prop- erties of thin film formed by tartrazine food additiveon 304L stainless steel insaline solution	Trisodium (4E)-5-oxo-1-(4-sulfonatophenyl)-4-[(4-sulfonatophenyl) hydrazo- no]-3-pyrazolecarboxylate, effect on the corrosion rate of 304L stainless steelused as canned food packaging has been studied by estimating the inhibitory properties of the organic film formed on the alloy surface during the electrochem-ical measurements performed in saline solution containing 0.9 % NaCl, without and with tartrazine inhibitor. AFM technique revealed the main surface changes of steel corroded in saline blank solution as well as in saline solution containing tartrazine food additive compared to standard stainless steel sample.
2	An update on the innova-tive surgical double-glovehole puncture indication systems: Reliability and performance	During operative procedures, operating room personnel wear sterile surgical gloves designed to protect them and their patients against transmissible infec-tions. The Food and Drug Administration (FDA) has set compliance policy guides for manufacturers of gloves. The FDA allows surgeons' gloves whose leakage de-fect rates do not exceed 1.5 acceptable quality level (AQL) to be used in operating rooms. The implications of this policy are potentially enormous to operating room personnel and patients. This unacceptable risk to the personnel and patient could be significantly reduced by the use of sterile double surgical gloves.
3	Testing the corrosion re-sistance of stainless steelsduring the fermentation of probiotic drink	Over recent years, food producers have devoted much attention to the production of safe foods. Simultaneously, using advanced process technologies, it has been necessary to carefully select materials for use in process equipment. Milk and its products are exposed to metal surfaces from the time they are processed, throughthe various stages of handling and manufacture, to the packaging of the finished products for market. The selection of suitable materials for daily use in the dairy industry cannot be governed solely by their price and mechanical properties but must also take into consideration their influence on the quality of milk products. The results indicated that Nb played the most protective role against corrosionduring kefir fermentation, since the steel containing Nb but no Mo showed the lowest corrosion rate.
4	The 04Kh19AFT nick-el-free stainless sheetsteel	Ferrite steel 04Kh119AFT has been developed. It may be obtained by integrated alloying chrome steel by Ti and V at the controlled content of interstitial impurities. Control one the Ti and V carbonitrides precipitates of most suitable sizes enhanc-es the ductility and deformability and makes the stamping of products of any size an forms easier. Field tests show that this corrosion-resistant steel is well welded,stamped, polished and liable to deep drawing when producing welded construc- tions. It is attraction for food engineering industry, automobile industry, householdappliances, etc.
5	Internal corrosion in domestic drinking-water installations	Domestic drinking-water installations involve the use of a variety of plumbing materials. This paper describes the correlation between material quality, plumbing and operational conditions and water quality. Specific attention is paid to galva-nized steel, copper and lead but the new plumbing materials stainless steel and plastic are also mentioned.
6	Superhydrophobic sys-tems in food science and technology: Concepts, trends, challenges, and technological innovations	The natural phenomenon of superhydrophobicity that occurs in plants and animalshas been a current topic for research and development with the goal of widening its applications. However, a more complete understanding of such surfaces is necessary to assess the effects of morphology, chemical structure, and surface roughness. In the food sector, such investigations tend to be at an early stage, although superhydrophobic surfaces (SHS) are known to hold promise for food packaging, processing, safety, and preservation. A review of the phenomenon of superhydrophobicity, the parameters to be evaluated for producing superhydro- phobic surfaces, and the main impact factors is presented.
7	Effective electrodeposition of poly(3,4-ethylene-dioxy- thiophene)-based organic coating on metallic food packaging for active corro-sion protection	Modern technologies continuously need special materials with specific proper-ties to adopt the desired application. Recently, numerous researches have been dedicated to the development of new food packaging materials that can ensure optimum protection of the packaged product. In this context, conducting poly-mers-based coatings were considered promising materials to be used as con-tact compounds in the packaging industries. Poly(3, 4-ethylenedioxythiophene) (PEDOT) films were electrochemically synthesized on two different metallic food packaging substrates, namely, tinplate and aluminum.

8	Passivation and Chemical Conversion Combined Multi-Elements Coating on Low Sn-Coated Steel for Corrosion Protection	In this work, the tinplate with 0.5 g•m^{-2} tin coating mass was prepared in orderto improve the economic benefit for food packaging field. We studied this low Sn-coated steel surface state and developed a process combined Mo-Mn-Al-P coating based on its special structure.
9	Corrosion of aluminum for beverage packaging in acidic media containingchlorides and copper ions	Corrosion of aluminum packaging plays an important role concerning eco- nomic and health issues. The effect of aggressive ions on the behavior of the AA3104-H19 alloy provides knowledge to the food and packaging industries to improve materials and also minimizes losses associated with the corrosion. Thisstudy evaluated the interaction of the AA3104-H19 alloy and beverage using model solutions containing chloride and copper at levels close to those found in soft drinks. Information about the corrosion electrochemical behavior of aluminum alloys used for food and beverage is very scarce.
10	Corrosion protection of metallic archaeological artefacts using parylene based removable barrier coating	Barrier films are used in wide range of industrial fields such as microelectronics, food packaging or anticorrosion layers to protect material against external envi-ronmental influences. Using of barrier films may be an alternative way of anticor-rosion protection and conservation of metallic archaeological objects and it is the aim of this study. Based on our previous work, polymer parylene (poly-p-xylylene) was chosen for preparation of thin films for this purpose thanks to its desirable properties such as excellent barrier properties, transparency and formation of conformai coating without defects.

A case study has been undertaken in this area.

CASE STUDY

2. EXPERIMENTAL

Ever silver Composition

Ever silver is an alloy of silver that consists of 92.5% pure silver and 7.5% other metal, usually copper[Figure 1]. The other metals in the alloy increase hardness, so the material will be durable.

Figure 1. Ever silver vessel containing curd rice

Curd

Curd is made by bacterial fermentation of milk. In this process, lactose in milk is converted into lac-tic acid by several probiotic microorganisms. The species involved in the fermentation depends onthe temperature and humidity of the environment and may include Lactococcus lactis, Streptococcus diacetylactis, Streptococcus cremoris, Lactobacillus delbrueckii subsp. bulgaricus and Streptococcus thermophilus [11].

Boiled rice

Plain boiled rice is cooked using rice and water. Rice and water are the raw materials required to make boiled rice hence are called ingredients [12].

Preparation of Curd Rice Recipe

Curd rice is also known as thayirsaddam, dahi chawal and daddojanam. A very simple dish made using the most basic ingredients, curd and rice with an authentic south-indian tempering does not take more than 15 minutes to cook.

Easy to make, the curd rice is made by mixing rice with tempering it with mustard an green chillies. Allow the rice to cool slightly before adding the curd, to avoid the curds from splitting. Many people con- sider South Indian curd rice to be the best dish to carry along to school, work or travel.

We have taken the following combinations for investigation.

Water system, (Water + Curd system), (Wa-ter + Curd + Rice system) and (Water + Curd+ Rice + Salt system).

Surface characterization study

The ever silver specimens were immersed in various test solutions for a period of one day. After one day the specimens were taken out and dried. The nature of the film formed on the metal surface was analyzed by surface characterization studies such as SEM,contact angle and Vickers hardness.

Scanning electron microscopy (SEM)

The mild steel specimens immersed in various test solutions for one day were taken out, dried and subjected to the surface examination. The surface morphology measurements of the mild steel surface were carried out by scanning electron microscopy (SEM) using CAREL ZEISS make model EVO-18.

Contact angle

The contact angle measurements on the sur- face were performed on a VCA Optima instrument equipped with a CCD camera for imaging. The deionized water under static conditions with a drop volume of 5 µl was employed to determine the con- tact angle. VCA Optima XC software provided with instruments was used for fitting the drop shapes to find the contact angle of water on the surface. This measurement was repeated three times for each sample, the average values with standard deviations ±2 are reported.

Vickers hardness

The ever silver specimens immersed in various test solutions for one day were taken out, rinsed with double distilled water, dried and subjected to Vick- er hardness. The Vicker hardness measurements of the mild steel surface were carried out by Shimadzumake model HMV-2T.

AC impedance spectra

AC impedance spectral studies were carried ou- ton a CHI – Electrochemical workstation with imped-ance. The corrosion resistance of ever silver elec- trode immersed in various test solutions has been measured. A three – electrode cell assembly was used. The working electrode was Ever silver elec- trode. A saturated calomel electrode (SCE) was the reference electrode and platinum was the counter electrode.

The real part (Z') and imaginary part (-Z'') of the cell impedance were measured in Ohms at various frequencies. Values of the charge transfer resistance (R_t) and the double layer capacitance (C_{dl}) were cal-culated from Nyquist plots and Bode plots.

3. RESULTS AND DISCUSSION

Ever silver is popularly used for cookware, kitch- en utensils and cutlery. This is because it is hard- wearing, corrosion resistant and it doesn't affect the flavour of the food when used for food storage or production. Due to the resistance levels, foods with high acidity won't cause damage. Usually, stu- dents take much variety rice in stainless steel. Inthis project we have taken water, water+curd, wa- ter+curd+rice and water+ curd+rice+salt (sodium chloride) systems, in a stainless steel. To identify whether ever silver has undergone corrosion or not, we have undertaken AC impedance spectra.

Analysis of results of AC impedance Spectra [Elec- trochemical Impedance Spectra (EIS)]

AC impedance spectra have been used to detect the formation of the film on the metal surface [13-17]. If a protective film is formed, the charge transfer re- sistance (R_t) increases, impedance value increases, phase angle value increases and double layer ca- pacitance (C_{dl}) value decreases (Figure 2).

The AC Impedance spectra of ever silver elec- trode immersed in various solutions are shown in Figures 3 to 6 (Nyquist plots) and Figures7 to 10 (Bode plots).The interactive 3D plots are shown in Figures 11 to 14.

The AC Impedance parameters, namely, charge transfer resistance (R_t), impedance value, phase angle value and double layer capacitance (C_{dl}) are given in Table 2.

Let us recollect the principles of AC impedance spectra and corrosion inhibition study.

"If a protective film is formed, the charges trans- fer resistance (R_t) increases, impedance value in- creases, phase angle value increases and double layer capacitance (C_{dl}) value decreases" (Figure 2).

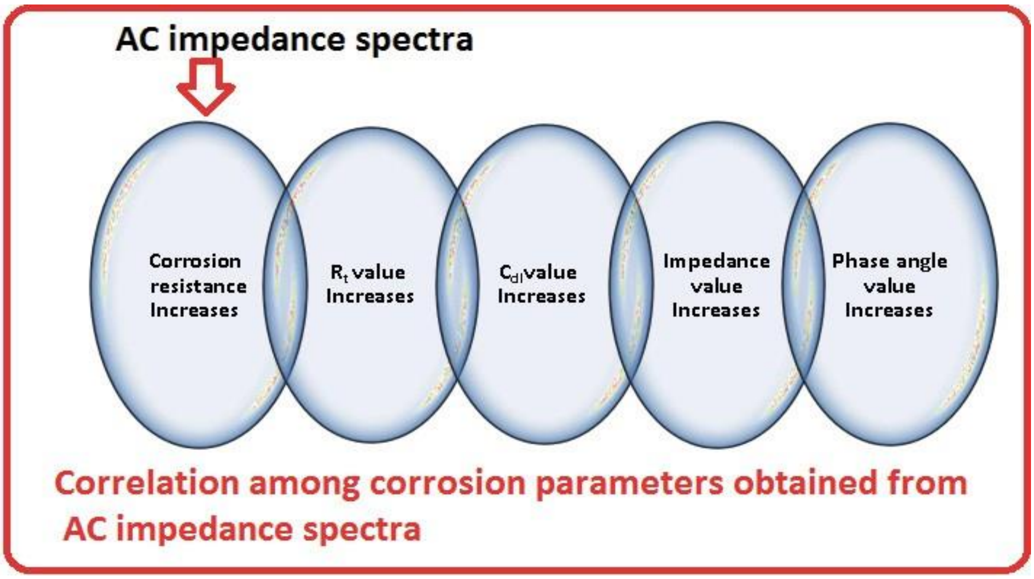

Figure 2. Correlation among corrosion parameters obtained from AC impedance spectra

Table 2. Corrosion parameters of Ever silver electrode immersed in various test solutions, obtained from AC Impedance spectra

System	Rt, Ohm.cm^2	Cdl, F/cm^2	Impedance Log(Z/Ohm)	Phase Angle^O
water	24.63	482.94x10^{-4}	1.675	0.0033
water+Curd	25.56	501.176x10^{-4}	2.047	0.100
Water+Curd+Rice	504	9882.35x10^{-4}	3.217	5.678
Water+Curd+Rice+Salt	32.99	646.86x10^{-4}	1.934	1.240

Interesting conclusions are derived from Table1.

Water system

When Ever silver electrode is immersed in water the charge transfer resistance (Rt) is 24.63 Ohm.cm^2. Dou- ble layer capacitance (Cdl) value is 482.94 x10^{-4} F/cm^2.

Water+curd system

When ever silver electrode is immersed in wa- ter+curd system, the corrosion resistance of ever silver electrode increases. This is due to the ad- sorption of molecules of the ingredients present in curd. When ever silver is electrode immersed in wa- ter+curd system the charge transfer resistance (R_t) is 25.56 Ohm.cm^2. Double layer capacitance (C_{dl}) value is 501.176x10^{-4} F/cm^2.

Water +curd+rice system

When ever silver electrode is immersed in wa- ter+curd+rice system, the corrosion resistance of Ever silver electrode further increases. This is due to the adsorption of molecules of the ingredients present in curd and boiled rice. When ever silver electrode is immersed in water+ curd+rice system the charge transfer resistance (R_t) is 504 Ohm.cm^2. Double layer capacitance (C_{dl}) value is 9882.35x10^{-4}F/cm^2.

Water+curd+rice+salt system

When Ever silver electrode is immersed in wa- ter+curd+rice+salt system, the corrosion resistance of ever silver electrode decreases.

When ever silver electrode is immersed in wa- ter+curd+rice+salt system the charge transfer resist- ance (R_t) is 32.99 Ohm.cm^2. Double layer capaci- tance (C_{dl}) value is 646.86x10^{-4} F/cm^2.

When ever silver electrode is immersed in water + curd rice system + 500 ppm sodium chloride sys- tem, the corrosion resistance of ever silver electrode decreases. This is due to the presence of chloride ion introduced into the curd rice system. It implies that when curd rice is packed in vessels made of ever silver, we should avoid adding salt to the curd rice. It is better to keep the salt and curd rice sepa- rately. It is to be noted that this corrosion resistance is better than the corrosion resistance in water alone.

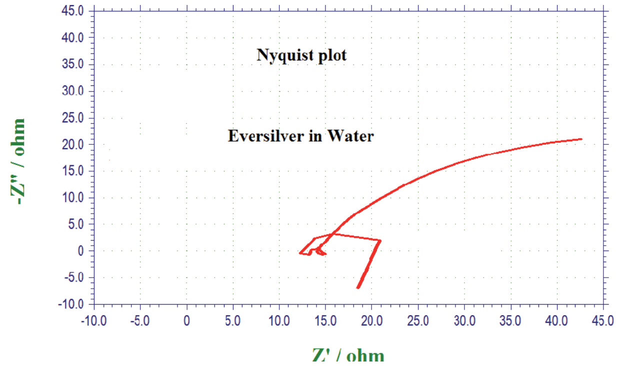

Figure 3. Nyquist plot of Ever silver electrode immersed in Water

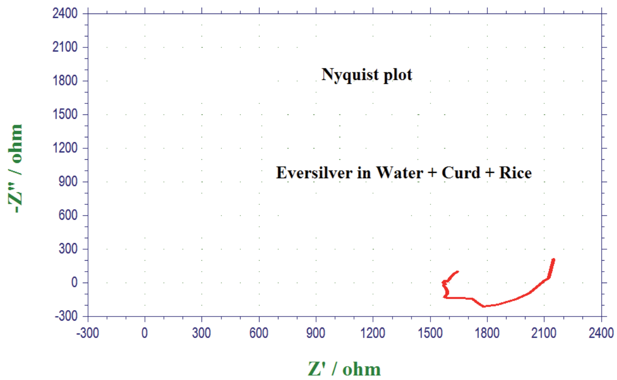

Figure 5. Nyquist plot of Ever silver electrode immersed in Water+Curd + Rice system

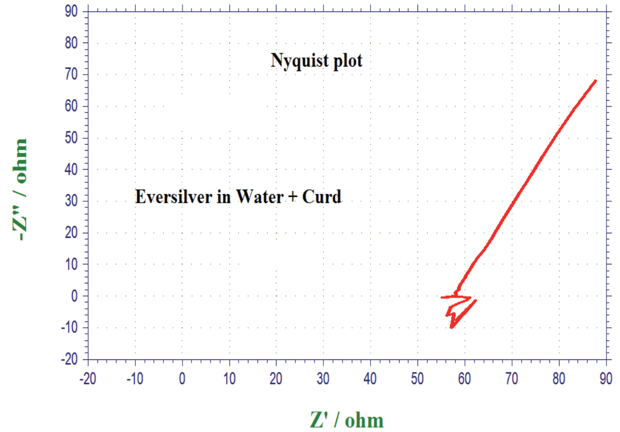

Figure 4. Nyquist plot of Ever silver electrode immersed in Water+ Curd system

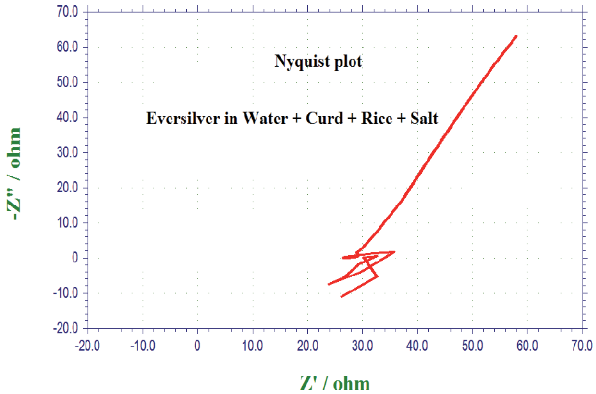

Figure 6. Nyquist plot of Ever silver electrode immersed in Water+ Curd+ Rice+ Salt system

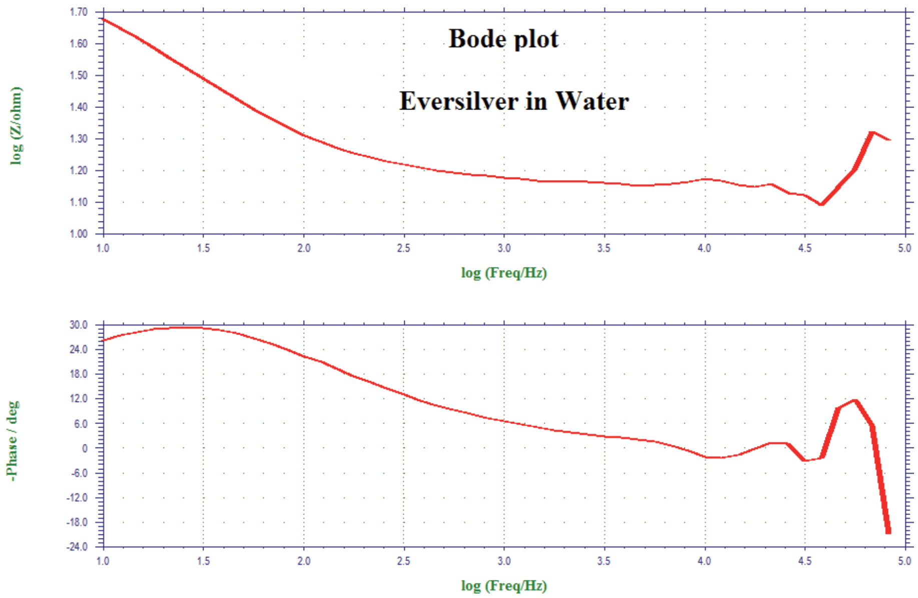

Figure 7. Bode plot of Ever silver electrode immersed inWater

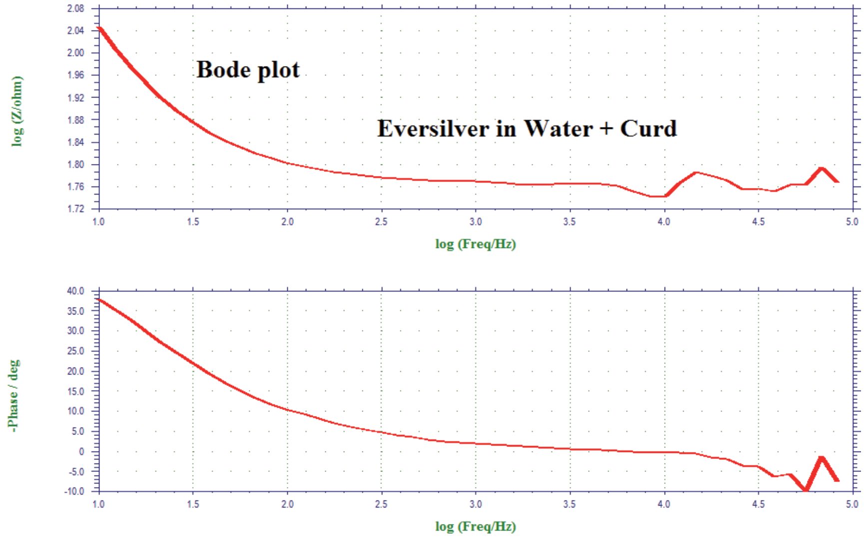

Figure 8. Bode plot of Ever silver electrode immersed in Water+ Curd system

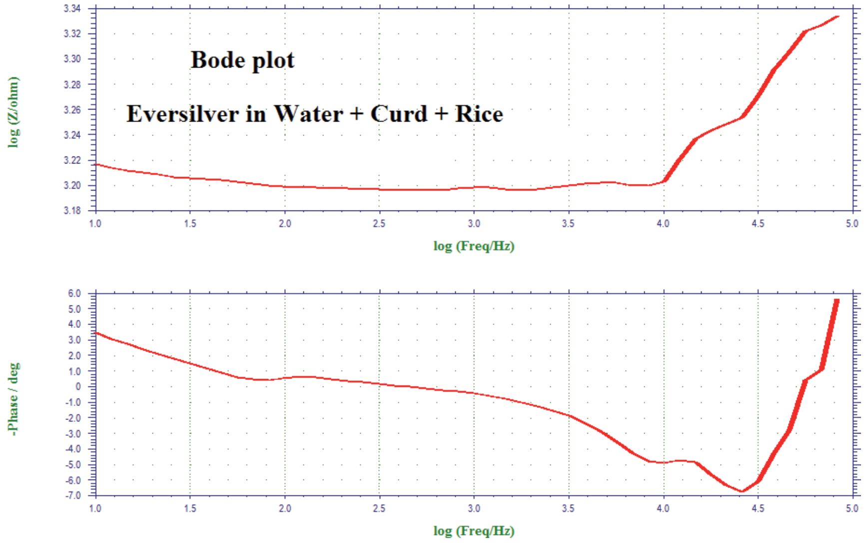

Figure 9. Bode plot of Ever silver electrode immersed in Water+Curd+ Rice system

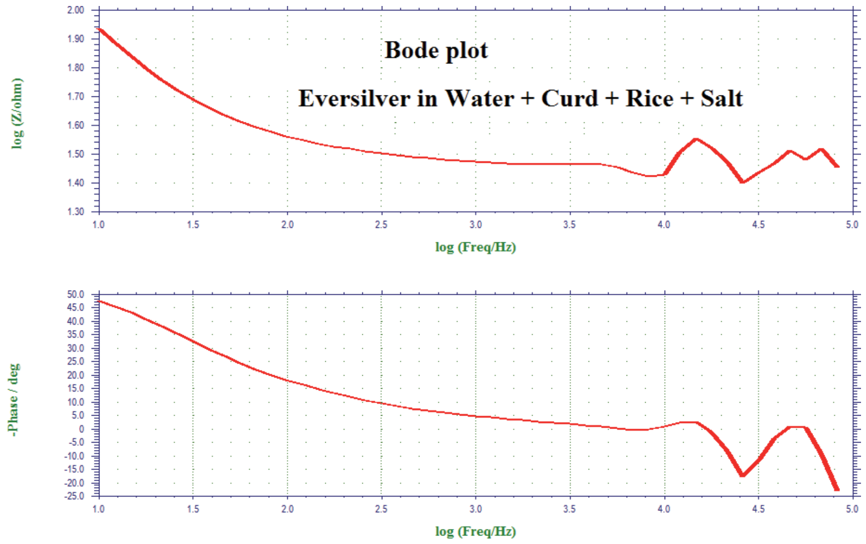

Figure 10. Bode plot of Ever silver electrode immersed in Water+Curd+Rice+Salt system

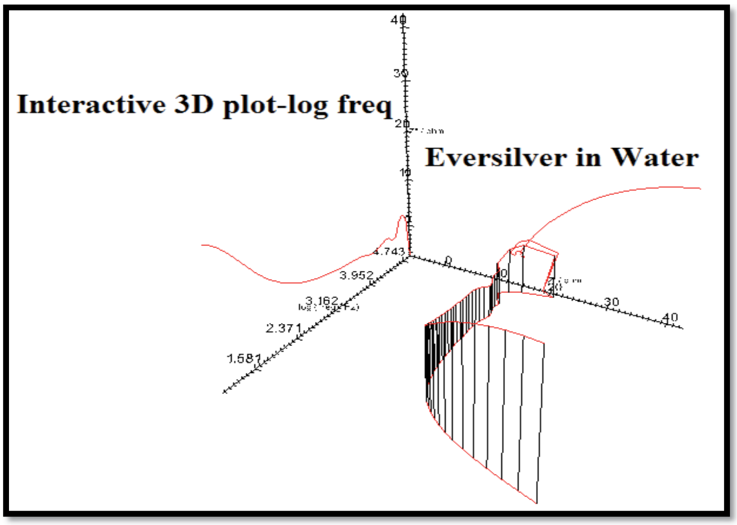

Figure11. Interactive 3D plot-log freq of Ever silver electrode immersed in Water system

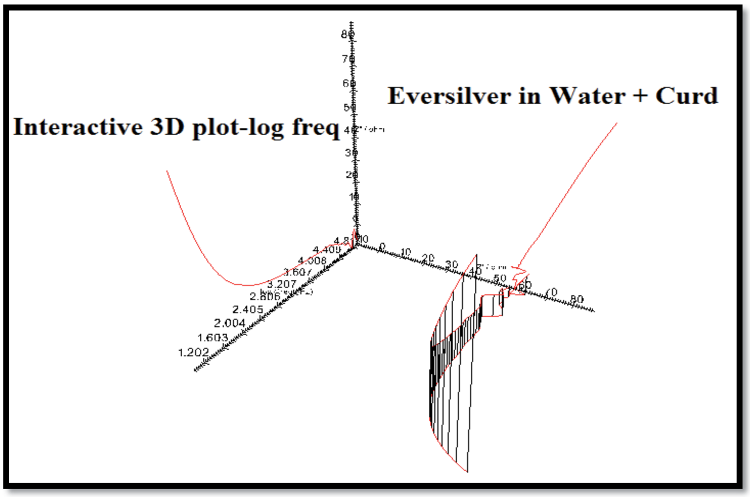

Figure 12. Interactive 3D plot-log freq of Ever silver electrode immersed inWater+Curd system

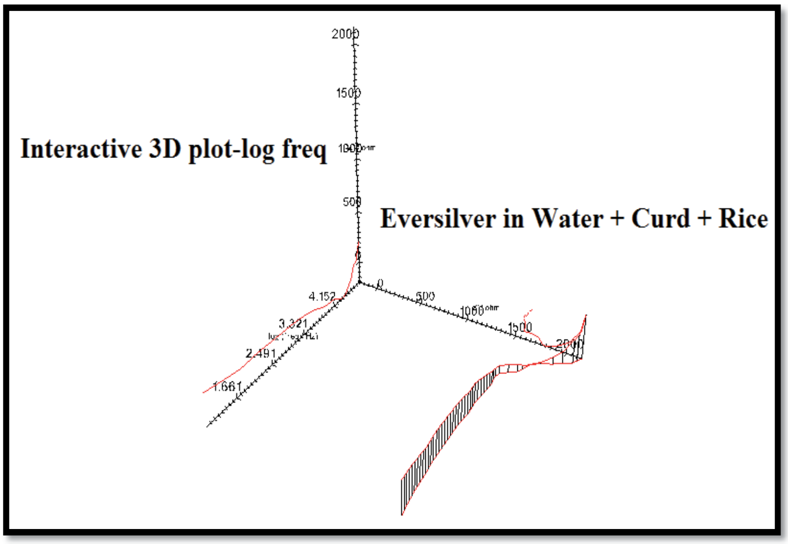

Figure 13.Interactive 3D plot-log freq of Ever silver electrode immersedin Water + Curd + Rice system

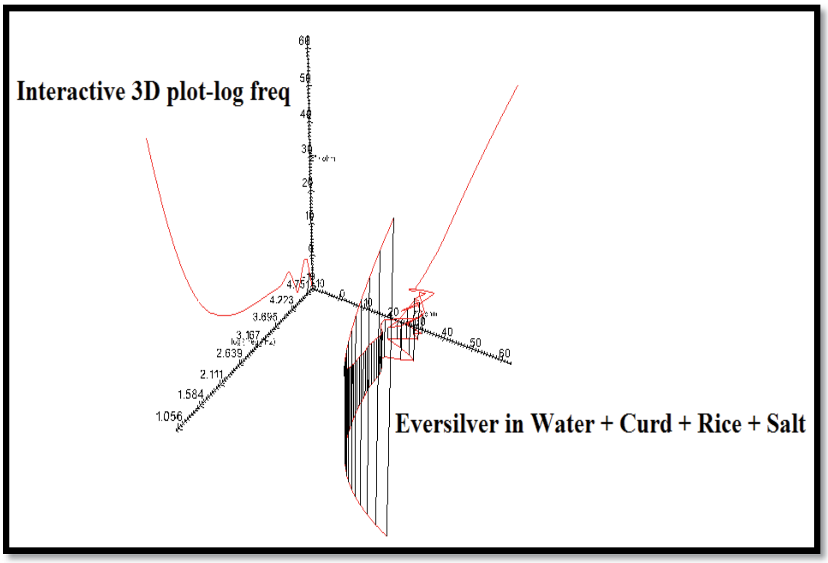

Figure 14. Interactive 3D plot-log freq of Eversilver electrode immersedin Water + Curd + Rice + Salt system

Analysis of surface morphology

Polarization study revealed that for ever silver + water + curd rice system the Charge transfer re- sistance value was higher (504 Ohmcm^2) than that for the ever silver + water + curd rice + salt (sodi- um chloride 500 ppm) system (32.99 Ohmcm^2). For these two systems surface morphology was ana- lysed using Vickers hardness measurement, SEM and contact angle measurement.

Vickers hardness (HV)

Vickers hardness (HV) has been used to meas- ure hardness of metal surfaces before corrosion andafter corrosion process [18-22].

In the present study the Vickers hardness (HV) of ever silver in Water+Curd+Rice systemand Wa- ter+Curd+Rice+Salt system have been calculated. This is due to the following reasons. In the first sys- tem ever silver has a LPR value of 504 Ohmcm^2. But in the second system the LPR value decreases due to corrosion process induced by chloride ions introducedinto the first system (Table3, Figure 15).

Table 3. Vickers hardness of various surfaces

System	Load	L1	L2	HV
Water+Curd+Rice	50 g	35.14	36.02	73.2
Water+Curd+Rice+Salt	50 g	49.41	51.79	36.2

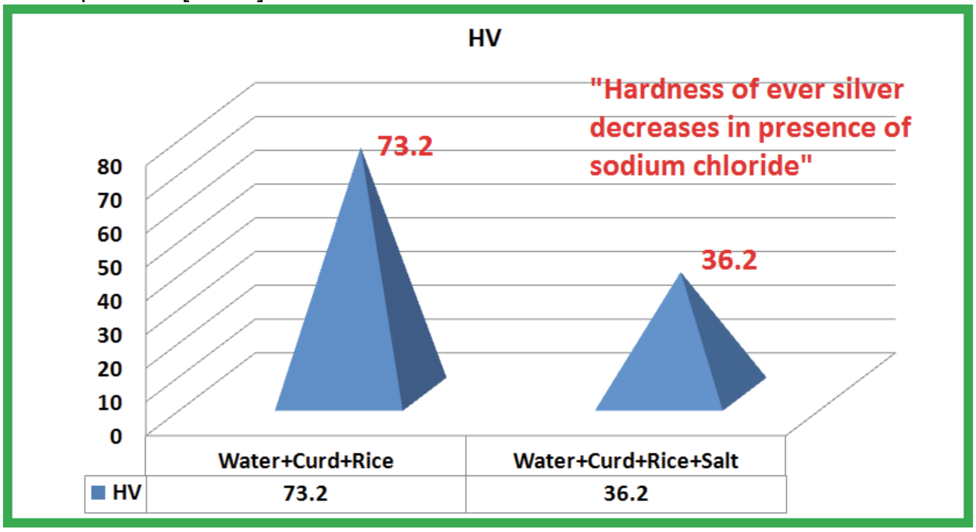

Figure 15. Comparison of Vickers Hardness values

Contact angle measurement

Contact angle measurements have been widely used in corrosion study[23-27]. The contact angles have been measured for ever silver immersed in Wa- ter+Curd+Rice systemand Water+Curd+Rice+Salt system (Figure 16). This is due to the following rea- sons. In the first system ever silver has a R (charge ue decreases due to corrosion process induced by chlo-ride ions introduced into the first system. It is observedthat contact angle for first system is higher (112.3°) than that for second system (99.1°). This indicates that the first system is hydrophobic (contact angle > 90°) and the later is less hydrophobic in nature. So in the first case water molecules could not reach the metal surface and so higher R (charge transfer resist transfer resistance) value of 504 Ohmcm. But in the se cond system the R_t (charge transfer resistance) val ance) value in AC impedance spectral study.

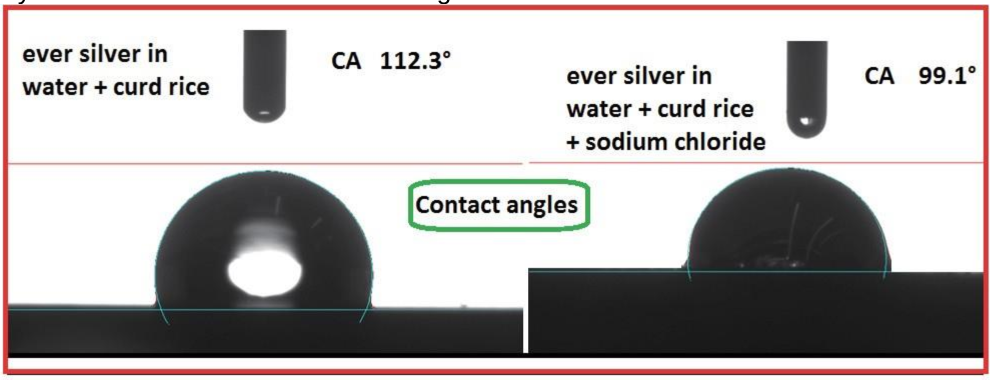

Figure16. Comparison of contact angle values

ANALYSIS OF SEM IMAGES

SEM images have been used in corrosion inhi- bition studies [28-32]. When the metal surface is in a corrosive medium corrosion resistance decreases and pits are noticed. The surface becomes rough. On the other hand in a corrosion protected system the metal surface is smooth. The SEM images of the surface of ever silver immersed in water + curd rice system and water + curd rice + sodium chloride (salt 500 ppm) are shown in Figure17. It is evident that ever silver has undergone corrosion when it is im- mersed in water + curd rice + sodium chloride (salt 500 ppm) system. Pits are noticed on the metal sur- face (Figure 17).

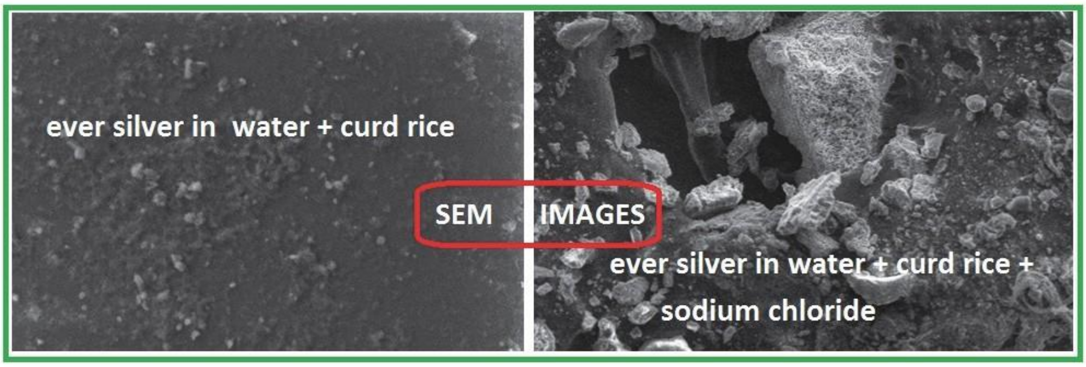

Figure 17. SEM images

CONCLUSION

- This project is undertaken to know ifEversil- ver vessels undergo corrosion or not, when they come in contact with some food items (recipes)
- AC impedance spectra have been employed to investigate the corrosion resistance of ever silver electrode when it is immersed in various test solutions like water, curd, curd rice recipe, curd rice recipe with salt (sodium chloride 500 ppm).
- The corrosion resistance of eversilver electrode when it is immersed in various test solutions like water, water+curd, wa- ter+curd+rice and water+curd+rice+salt have been evaluated by AC impedance spectroscopy.
- If a protective film is formed, the chargetransfer resistance increases, impedance value incre- ases, phase angle value increas-es and double layer capacitance (Cdl) valuedecreases.

- When Ever silver electrode is immersed in water + curd rice system + 500ppmsodium chloride system, the corrosion resistance of eversilver electrode decreases. This is due to the presence of chloride ion introduced into the curd rice system. It implies that when curd rice is packed in vessels made of eversilver, we should avoid adding salt to the curd rice. It is better to keep the salt andcurd rice separately. It is to be noted that thiscorrosion resistance is better than the corro-sion resistance in water alone.
- The corrosion resistance decreases in the following order:

Water + Curd + Rice system > Water + Curd + Rice + Salt system (sodium chloride 500ppm) >Wa- ter+Curd system > Water

SCOPE FOR FURTHER STUDIES

The present work is undertaken to investigate thecorrosion inhibition of ever silver in the presence of water, water+curd system, water+curd+rice system,water+curd+rice+salt system.

The corrosion resist- ance has been evaluated by AC impedance spectra .

In future the following study can be undertaken

- Instead of curd other food item can be used.
- Instead of ever silver other metals can be used.
- Surface analysis such as AFM, FTIR, EDAX., can be employed.

Acknowledgements

The authors are thank ful to their respective man-agements for their help and support

REFERENCES

[1] A.Samide, G.E.Iacobescu, B.Tutunaru, C.Tigae (2017) Electrochemical and AFM study of inhibitory properties of thin film formed by tartrazine food ad- ditive on 304L stainless steel in saline solution, Inter- national Journal of Electrochemical Science, 12(3), 2088–2101.

[2] R.F.Edlich, T.C.Wind, C.L.Heather, J.G.Thacker (2017) An update on the innovative surgical dou- ble-glove hole puncture indication systems: Reliabil- ity and performance, Journal of Long-Term Effects ofMedical Implants, 27(2-4), 339–353.

[3] D.Pečar, M.Slemnik, A.Goršek (2011) Testing the corrosion resistance of stainless steels during the fer- mentation of probiotic drink, Journal of the Science ofFood and Agriculture, 91(7), 1293–1297. Doi: https://doi.org/10.1002/jsfa.4315

[4] K.A.Yushchenko, R.I.Morozova, Yu.N.Kakhovskij, G.F.Nastenko, E.V.Mokrov (1992) The 04Kh19AFT nickel-free stainless sheet steel, Stal’, 4, 69–70.

[5] I.Wagner (1992) Internal corrosion in domestic drinking-water installations, J. Water supplyresearch & Technology-aqua, 41(4), 219–223.

[6] M.M.Frota, A.L.A.Mattos, K.W.E.Miranda, H.N. Cheng, A.Biswas, M.D.S.R.Bastos (2022) Super- hydrophobic systems in food science and techno- logy: Concepts, trends, challenges, and technolo- gical innovations, Ap- plied Food Research, 2(2), 100213. Doi: https://doi. org/10.1016/j.afres.2022.100213

[7] A.El Guerraf, S.Ben Jadi, Z.Aouzal, M.Bouabdal- laoui, N.K. Bakirhan, S.A.Ozkan, M.Bazzaoui, E.A.Bazzaoui, (2022) Effective electrodeposition of poly(3,4-ethylenedioxythiophene)-based organic coating on metallic food packaging for active corro- sion protection, Journal of Applied Electrochemistry, 52(9), 1383–1407.

[8] Y.Zhao, X.Yin, P.Shen, N.Li, Y.Xu (2022) Passiva- tion and Chemical Conversion Combined Multi-Ele- ments Coating on Low Sn-Coated Steel for Corrosion Protection, Journal of the Electrochemical Society, 169(8), 082501. Doi: 10.1149/1945-7111/ac7efa

[9] B.M.C.Soares, S.T.Dantas, C.A.R.Anjos (2017) Cor- rosion of aluminum for beverage packaging in acidic media containing chlorides and copper ions, Journal of Food Process Engineering, 40(6), e12571. Doi: https://doi.org/10.1111/jfpe.12571

[10] L.Blahova, J.Horak, R.Prikryl, F.Krcma (2016) Cor- rosion protection of metallic archaeological artefacts using parylene based removable barrier coating, Eu- ropean Corrosion Congress, EUROCORR 2016, 3, 1723–1731.

[11] https://en.wikipedia.org/wiki/Dahi_(curd)

[12] https://www.google.com/search?q=boiled+rice+in- gredients&source=lmns&bih=612&biw=1366&prm- d=isvnmbtz&hl=en&sa=X&ved=2ahUKEwi-kqTGn- MuFAxWrnGMGHZ_mB-UQ0pQJKAB6BAgBEAI

[13] A.Krishnaveni, N.Anitha, V.Velkannan, D.Sarmina, T.Shanthi, G.Singh, H.Abdulhameed, S.Rajendran, C.Lacnjevac (2022) Inhibition of corrosion of L 80 alloy pipeline carrying simulated oil well water by succinic acid | Inhibicija korozije cevovoda od legure l 80, koji nosi simuliranu vodu iz bunara, ćilibarnom kiselinom, Materials Protection, 63(4), 454–462. Doi: https://doi.org/10.5937/zasmat2204454K

[14] P.Shanthy, K.Kavipriya, A.Santhiya Brintha, G.Pri- yanka, K.Vigneswari, V.Velkannan, G.Singh, A.Al Hashem, A.Nilavan, S.Rajendran, C.Lacnjevac (2022) Influence of thiourea on the corrosion resistance of mild steel immersed in simulated concrete pore solu- tion, Materials Protection, 63(4), 447–453.

[15] A.Nilavan, L.Jewelcy Arockiaraj, A.A.Thomas Antony, C.M.Velankanni Jeevitha, R.Jeyalakshmi, A.Roslin, P.Murugesh, V.Velkannan, G.Singh, A.Al Hashem, S.Rajendran, A.Krishnaveni (2023) Corrosion resist- ance of mild steel immersed in simulated concrete pore solution in the presence of sodium potassium tartrate, Materials Protection, 64(2), 170–176.
Doi: https://doi.org/10.5937/zasmat2302170N

[16] R.S.S.Kumar, R.S.S.Kumar, S.Ramalingam, S.S.Swe-tha, A.S.Ra. Mariya Selastina, F.X.Punitha Pricilla, S.J.Ramesh, M.Sathya Priya, S.Hema Dharshini, R.Yuva Sri, A.Nilavan, S.Rajendran (2023) Inhibition of corrosion of L 80 alloy in sodium hydroxide solution (pH=12) by succinic acid, Materials Protection, 64(1),78–85.

Doi: https://doi.org/10.5937/zasmat2301078K

[17] S.Rajendran, A.Al-Hashem, A.Krishnaveni, L.J.Aro-ckiaraj, G.Singh, C.Lacnjevac, M.N.Jothi, P.Shanthy (2024) Corrosion inhibition by fruit extracts-Inhibi-tion of corrosion of mild steel in simulated concrete pore solution prepared in sea water by an aqueous extract of apple juice-A Case study, Materials Pro-tection, 65(1), 22–34. Doi: https://doi.org/10.62638/ZasMat1040

[18] V.Jeslina, S.J.Kirubavathy, A.Al-Hashem, S.Rajen-dran, R.M.Joany, C.Lacnjevac (2023) Mild Steel Cor- rosion Inhibition in 1 M HCl by an Alcoholic Extract of Sargassum Muticum, Portugaliae Electrochimica Acta, 41(2), 151–165.

[19] J.J.M.Praveena, J.A.Clara, S.S.Rajendran, A.J.Amal- raj (2021) Inhibition of corrosion of mild steel in well water by an aqueous extract of soapnut (Sapindus Trifoliatus) Materials Protection, 62(4), 277–290.

Doi:https://doi.org/10.5937/zasmat2104277P

[20] R.Dorothy, T.Sasilatha, S.Rajendran (2021) Corrosionresistance of mild steel (Hull plate) in sea water in thepresence of a coating of an oil extract of plant ma- terials, International Journal of Corrosion and Scale Inhibition, 10(2), 676–699. Doi: doi: 10.17675/2305- 6894-2021-10-2-13

[21] A.S.Prabha, K.Kavitha, H.B.Shrine, S.Rajendran (2020) Inhibition of corrosion of mild steel in simulated oil well water by an aqueous extract of Andrographis paniculata, Indian Journal of Chemical Technology, 27(6), 452–460. Doi: 10.56042/ijct.v27i6.33654

[22] A.Casaroli, M.V.Boniardi, B.Rivolta, R.Gerosa, F.Ia-coviello (2023) Metallurgical Failure Analysis of Closed Water Circuit Containing Molybdate-Based Inhibi- tor, Metals, 13(4), 723.

Doi: https://doi.org/10.3390/ met13040723

[23] X.Luo, B.Chen, J.Li, C.Zhou, M.Guo, K. Peng, H.Dai, B.Lan, W.Xiong, Y.Liu (2024) Zwitterion modified chi-tosan as a high-performance corrosion inhibitor for mild steel in, hydrochloric acid solution, International Journal of Biological Macromolecules, 267, 131429.

Doi: https://doi.org/10.1016/j.ijbiomac.2024.131429

[24] G.D.Pai, M.R.Rathod, R.S K, A.A.Kittur (2024) Effect of tabebuia heterophylla plant leaves extract on cor- rosion protection of low carbon steel in 1M HCl medi- um: Electrochemical, quantum chemical and surface characterization studies, Results in Surfaces and In- terfaces, 15, 100203.

Doi: https://doi.org/10.1016/j. rsurfi.2024.100203

[25] M.A.Abd El-Ghaffar, N.M.Nooredeen, E.A.Youssef, A.-R.M.Mousa (2024) Alkyd coating containing metal phosphomolybdate/cobalt ferrite nanocom-posites as efficient corrosion inhibitor for stainless steel 316L in saline solution, Journal of Industrial and Engineering Chemistry, 132, 86–110. Doi: https://doi.org/10.1016/j.jiec.2023.10.044

[26] O.Kharbouch, K.Dahmani, N.Errahmany, A. Belkheiri, M.Galai, F.El Hajri, A.A.Alobaid, I. Warad, S.Boukhris, M.Ebn Touhami, H.Nassali (2024) Enhancing Cor- rosion Resistance of Mild Steel in 1M HCl: Investi- gation of New Benzoxazepine Derivatives Through Synthesis, Electrochemical Analysis, Surface Analy- sis, XPS, DFT, and Molecular Dynamics Simulation, Chemistry Select, 9(15), e202303045.

Doi: https://doi.org/10.1002/slct.202303045

[27] X.Gao, Y.Gao, H.Cao, J.Zhang (2024) Eco-Friendly Sustainable and Responsive High-Performance Ben- zotriazole-Metal Organic Frameworks/Silica Compos- ite Coating with Active/Passive Corrosion Protection on Copper, Langmuir, 40(14), 7639–7652. Doi: https://doi.org/10.1021/acs.langmuir.4c00328

[28] A.Elsamman, K.F.Khaled, S.A.Halim, N.S. Abdelshafi (2024) Gravimetric and electrochemical evaluation of environmentally novel nanopyrazole derivatives for 304 SS in acidic solution: AFM, SEM/EDX, con- tact angle, and DFT/MDs simulations, Journal of Molecular Structure, 1309, 138157.

Doi: https://doi. org/10.1016/j.molstruc.2024.138157

[29] S.Alami, O.Moumouche, H.E.Harmouchi, M.Ouakki, R.Khaoulaf, K.Brouzi, N.Dkhireche, M.Harcharras (2024) Enhancing steel corrosion resistance in 1.0 M HCl medium through the synthesized and character- ized mixed pyrophosphates BMnP2O7 (B = Ni, Co, and Cd), Journal of Molecular Structure, 1309, 138182. Doi:

https://doi.org/10.1016/j.molstruc.2024.138182

[30] A.Mohammadkhani, F.Mohammadkhani, N.Farhad-yar, M.S.Sadjadi, E.Kianfar (2024) Novel nanocom-posite zinc phosphate/ polyvinyl alcohol / carbox-ymethyl cellulose: Synthesis, characterization and investigation of antibacterial and anticorrosive prop-erties, Case Studies in Chemical and Environmental Engineering, 9, 100591.

Doi: https://doi.org/10.1016/j.cscee.2023.100591

[31] G.Wei, S.Deng, D.Xu, J.Xu, D.Shao, X.Li (2024) Inva- sive weed of Eupatorium Adenophora Spreng leaves extract as a novel efficient inhibitor for the corrosion of cold rolled steel in chloroacetic acid solution, Jour- nal of Molecular Liquids, 400, 124501.

Doi: https://doi.org/10.1016/j.molliq.2024.124501

[32] H.M.K.Sheit, S.M.Kani, M.A.Sathiq, K.S.Mohan, S.S.S.Abuthahir (2024) Anti-corrosive Efficiency of Expired Propranolol Drug as a Corrosion Inhibitor on Mild Steel in Acid Medium, High Temperature Cor- rosion of Materials, 101(2), 351–367. DOI: 10.1007/ s11085-024-10227-0

IZVOD

UTICAJ NATRIJUM HLORIDA NA OTPORNOST NA KOROZIJU SREBRNIH POSUDA U PRISUSTVU PIRINČA

Ovaj rad je napisan kako bi se istražila otpornost na koroziju srebra u prisustvu vode, sistema voda+- gruša, sistema voda+skuta+pirinač, voda+sir+pirinač+so. Otpornost na koroziju je procenjena spek- trima impedanse naizmenične struje. Spektri impedanse naizmenične struje su korišćeni da se ispita otpornost na koroziju srebrne elektrode kada je uronjena u različite test rastvore kao što su voda, skuta, recept za sirni pirinač, recept za sirni pirinač sa solju (natrijum hlorid 500 ppm). Otpornostna koroziju srebrene elektrode kada je uronjena u različite test rastvore kao što su voda, voda+sir, voda+skuta+pirinač i voda+suta+pirinač+sol procenjena je spektroskopijom AC impedanse. Ako se formira zaštitni film, otpor prenosa naelektrisanja se povećava, povećava se vrednost impedanse, povećava se vrednost faznog ugla i smanjuje se vrednost kapacitivnosti dvostrukog sloja (Cdl). Kadase srebrna elektroda uroni u vodu + sistem pirinča + 500ppms sistem natrijum hlorida, otpornost na koroziju svake srebrne elektrode se smanjuje. Ovo je zbog prisustva hloridnog jona unešenog usistem skute pirinča. To implicira da kada se pirinač pakuje u posude napravljene od srebra, treba izbegavati dodavanje soli u skutu. Bolje je držati so i skutu odvojeno. Treba napomenuti da je ova otpornost na koroziju bolja od otpornosti na koroziju samo u vodi. Otpornost na koroziju se smanjuje sledećim redosledom: sistem voda + skuta + pirinač > voda + skuta + pirinač + so sistem (natrijum hlorid 500ppm) > sistem voda + skuta > voda

Ključne reči: *otpornost na koroziju, srebro, skuta, natrijum hlorid, elektrohemijska ispitivanja*
ORCID Numbers of all the authors

Naučni rad
Rad primljen: 15.05.2024.
Rad prihvaćen: 05.06.2024.