Corrosion resistance of orthodontic wire made of Gold 18K alloy in artificial saliva in the presence of Éclairs milky candy

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Abstract

Corrosion resistance of an orthodontic wire made of Gold 18K alloy immersed in artificial saliva in the absence and presence of 500 ppm of Éclairs milky candy has been investigated by polarization study and AC impedance spectroscopy. It is observed that corrosion resistance of Gold 18K alloy immersed in artificial saliva in the presence of 500 ppm of Éclairs milky candy increases. Hence it is concluded that people clipped with orthodontic wire made of Gold 18K alloy need not worry about taking Éclairs milky candy orally. When Gold 18K alloy is immersed in artificial saliva in the presence of 500 ppm of Éclairs milky candy, Linear Polarization Resistance value increases from $4.84 \cdot 10^6$ Ohm·cm^2 to $9.34 \cdot 10^6$ Ohm·cm^2; corrosion current decreases from $7.73 \cdot 10^{-9}$ A/cm^2 to $3.57 \cdot 10^{-9}$ A/cm^2; charge transfer resistance value increases from $1.72 \cdot 10^5$ Ohm·cm^2 to $2.16 \cdot 10^5$ Ohm·cm^2; impedance value increases from 5.48 to 5.78 Log(Z/Ohm); double layer capacitance decreases from $2.70 \cdot 10^{-11}$ F/cm^2 to $2.36 \cdot 10^{-11}$ F/cm^2, and phase angle increases from 44.68° to 45°. It is therefore concluded that people clipped with orthodontic wire made of Gold 18K alloy need not hesitate to take Éclairs milky candy orally. The findings of this study may find application in pediatric dentistry. The surface morphology of films formed on Gold 18K has been analyzed by AFM. It is inferred that (*i*) for Polished Gold 18K in AS + Éclairs milky candy, the AFM parameters are very low. This is due to the smoothness of the protective film formed on Gold 18K surface, (*ii*) for Polished Gold 18K in AS the AFM parameters are very high. This is due to the formation of corrosion products on Gold 18K surface, and (*iii*) for Polished Gold 18K system the AFM parameters are in between those of the two systems.

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Introduction

Beautiful objects are symmetrical in nature. Symmetry leads to beauty. Symmetry is a result of regular arrangement. Regular arrangement of teeth leads to attractive and beautiful smiles which attract everyone. Unfortunately, by God's grace, some people do not have regularly arranged teeth. To regularize the growth of teeth, people need the help of dentists. They make use of orthodontic wires made of various alloys such as SS 316 L, SS 18/9, NiTi, NiCr *etc*., after clipping these wires, people take many tablets, food items and juices orally. Because of these activities the orthodontic wires undergo corrosion. In addition, in the oral environment, in presence of saliva, which contains 98% water, plus electrolytes, mucus, white blood cells, epithelial cells (from which DNA can be extracted), glycoproteins, enzymes (such as amylase and lipase), antimicrobial agents such as secretory IgA and lysozyme, the orthodontic wires undergo corrosion further. Many investigations have been carried out on the corrosion resistance of several orthodontic wires in artificial saliva in the presence of food items, tablets, juices and candies.

Kamiński *et al*. have investigated the effect of glow discharge nitriding on the corrosion resistance of stainless steel orthodontic arches in artificial saliva solution. They have carried out a comparative study on orthodontic arch-wires AISI 304 steel before and after low temperature plasma nitriding. Polarization study and AC impedance spectroscopy have been employed for this purpose. Microhardness was measured before and after treatment [1]. The influence of snake fruit extract (*Salacca zalacca*) in inhibiting the release of chromium (Cr) and nickel (Ni) ion from stainless steel orthodontic wire to saliva has been investigated by Erwansyah and Susilowati. Cr and Ni ion release was measured using atomic absorption spectrophotometry. The investigation was made on control group and treatment groups. Pre-tests and post-tests were conducted. It is evident from this study that Snake fruit seeds extract effectively inhibits the Ni ions release from stainless steel orthodontic wire at a concentration of 300 ppm [2]. Musa Trolic *et al*. have examined the influence of probiotic supplements recommended for use in orthodontic patients on the corrosion stability of stainless steel and three types of NiTi orthodontic wires. The corrosion resistance was measured by polarization study and AC impedance spectra. It was observed that probiotic bacteria *L. reuteri* and probiotic supplement influence on a general corrosion rate as well as on likelihood of pitting corrosion occurrence. It was also noticed that their effect is dependent on the type of alloy and coating [3]. The degradation of metals and alloys in the human body is a combination of effects due to corrosion and mechanical activities. In dentistry, 316L stainless steel are used in a variety of applications: sterilized instruments, endodontic files in root canal therapy, metal posts in root canal treated teeth, temporary crowns, arch wires and brackets in orthodontics, a necessary condition for these applications must to resist to pitting corrosion

[4]. Antibacterial, antifungal and anticorrosion studies for the effect of hydroxyapatite (HA) coating on an orthodontic alloy have been investigated by Khamis and Jabar Almakzomi. The antibacterial and antifungal activities of HA coating against various bacteria and different types of *Candida* have been estimated [5]. Influence of some tablets on corrosion resistance of orthodontic wires made of SS 316L alloy in artificial saliva has been studied by Anandan *et al*. by means of electrochemical studies such as polarization study and AC impedance specta [6]. Renita D'souza *et al*. have measured corrosion resistance of SS 316L alloy in artificial saliva in presence of Sparkle fresh toothpaste, by electrochemical studies [7]. Agnes Brigitta *et al*. have studied corrosion resistance of SS18/8, Gold 18 carat, Gold 22 carat and SS 316L alloy in artificial saliva in the absence and presence of Vitavion Fort tablet 500 mg [8]. Influence of D-glucose on corrosion resistance of SS 316 L in presence of artificial saliva has been studied by Saranya and Rajendran by means of electrochemical studies [9]. Zhang *et al*. have investigated the effect of the heat treatment on corrosion and mechanical properties of CoCrMo alloys manufactured by selective laser melting [10]. Gowri *et al*. have investigated the influence of Metformin Hydrochloride 250 mg (MFH) tablet on corrosion resistance of orthodontic wire made of NiCr alloy in artificial saliva [11]. Corrosion resistance of stainless steel orthodontic wire in saliva in presence of watermelon rind extract has been investigated by Nahusona and Koriston by means of electrochemical studies. It is noted that the corrosion resistance of stainless steel orthodontic wire in saliva in presence of watermelon rind extract increases [12]. In the present work corrosion resistance of Gold 18K alloy in artificial saliva in the presence and absence of Éclairs milky Candy has been investigated by electrochemical studies such as polarization study and AC impedance spectroscopy.

Experimental

Preparation of the metal specimens

18K gold

The 18 Karat gold comprises of 75% gold mixed with 25% of other metals such as copper and silver. This type of gold is used to make stone studded jewelry and other diamond jewelry. It is less expensive compared to 24K and 22K gold. A thin wire of 18 karat gold is used as test material for this work.

Éclairs milky candy

Ingredients

Glucose syrup, sugar, whole MILK powder, palm oil, cocoa butter, cocoa mass, skimmed MILK powder, whey permeate powder (from MILK), MILK fat, emulsifiers (E471, (mono- and di-glycerides of fatty acids) E442, (commonly identified as soy lecithin) sunflower

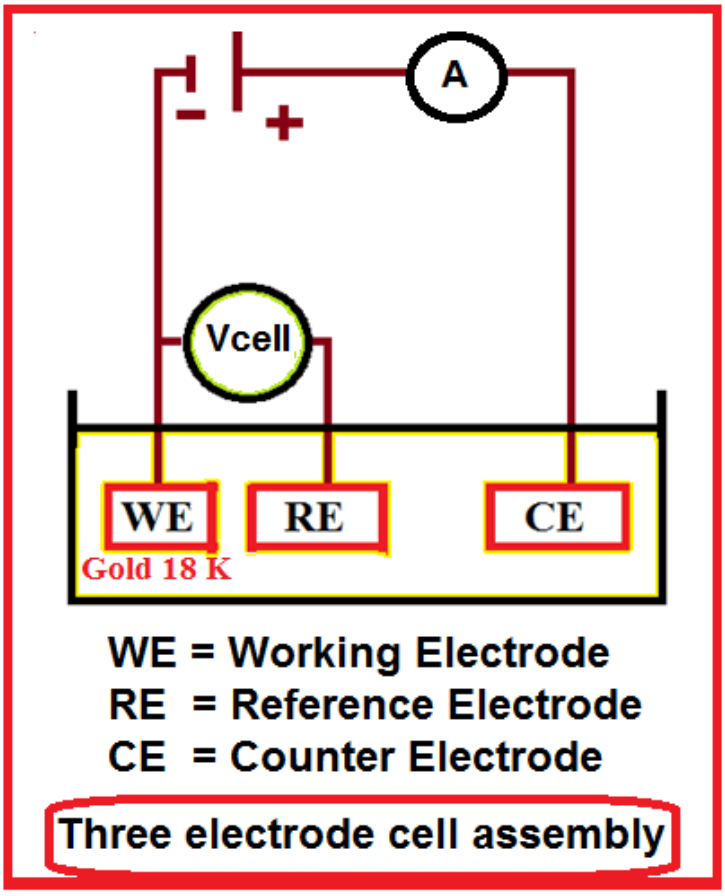
lecithin), salt, flavorings, acidity regulator (sodium carbonates). Salt: 0.48 g, fat: 17 g, protein: 4.2 g, (of which saturates): 9.1 g.

Preparation of artificial saliva

The preparation of artificial saliva was done using the composition of Fusayama Meyer artificial saliva (AS). Artificial saliva was prepared in laboratory and the composition of artificial saliva was as follows: KCl – 0.4 g/L, NaCl – 0.4 g/L, $CaCl_2 \cdot 2H_2O$ – 0.906 g/L, $NaH_2PO_4 \cdot 2H_2O$ – 0.690 g/L, $Na_2S \cdot 9H_2O$ – 0.005 g/L, urea – 1 g/L.

Potentiodynamic polarization study

A CHI 660A workstation model was used in the electrochemical studies. Polarization study was carried out using a three-electrode cell assembly (Scheme A). 18K gold was used as the working electrode, platinum as the counter electrode, and saturated calomel electrode (SCE) as the reference electrode. After having done iR compensation, the polarization study was carried out at a sweep rate of 0.01 V/s. The corrosion parameters such as linear polarization resistance (LPR), corrosion potential E_{corr}, corrosion current I_{corr} and Tafel slopes (b_a and b_c) were measured.



Scheme A. Three electrode cell assembly.

Alternating current impedance spectroscopy

AC impedance spectra were recorded in the same instrument used for polarization study, using the same type of three electrode cell assembly. The real part (Z') and imaginary part ($-Z''$) of the cell impedance were measured in Ohms for various frequencies. The charge transfer resistance (R_t) and double layer capacitance (C_{dl}) values were calculated.

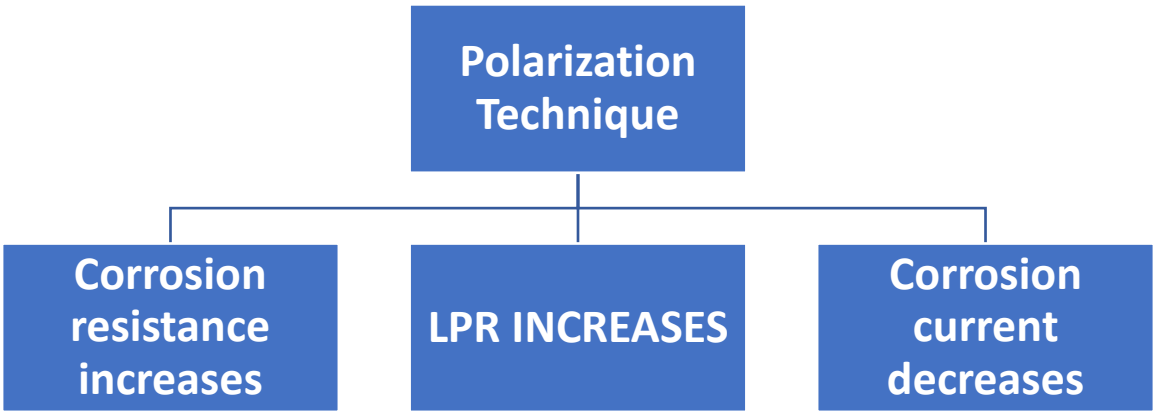
Atomic force microscopy (AFM)

The mild steel specimens immersed in various test solutions for one day were taken out, rinsed with double distilled water, dried and subjected to the surface examination. The surface morphology measurements of the mild steel surface was carried out by atomic force microscopy (AFM) using SPM Veecodi Innova connected with the software version V7.00 and the scan rate of 0.7 Hz.

Results and Discussion

Influence of Éclairs milky candy on corrosion resistance of Gold 18K alloy in artificial saliva

The influence of Éclairs milky candy on corrosion resistance of Gold 18K alloy in artificial saliva (AS), has been investigated by polarization study and AC impedance spectroscopy [13–27]. When corrosion resistance increases, linear polarization resistance increases, charge transfer resistance increases and impedance value increases. On the other hand, corrosion current decreases and double layer capacitance decreases (Scheme B).



Scheme B. Correlation among corrosion parameters of polarization study.

Polarization study

The polarization curves of 18K Gold alloy in artificial saliva (AS) in the absence and presence of 500 ppm of Éclairs milky candy are shown in Figure 1. The corrosion parameters

are given in Table 1. It is observed from Table 1 that in the presence of Éclairs milky candy, the corrosion resistance of 18K Gold alloy in AS increases. This is revealed by the fact that, in the presence of Éclairs milky candy, LPR value of Gold 18K alloy increases (Scheme B, Figure 1) and corrosion current decreases.

It is also observed that in the presence of Éclairs milky candy the corrosion potential shifts from –87 to –612 mV *vs*. SCE (Figure 1). It is inferred that in the presence of Éclairs milky candy the cathodic reaction is controlled predominantly. It behaves as cathodic inhibitor since this candy contains the ingredients given in experimental section

Implication

Corrosion resistance of Gold 18K in artificial saliva decreases in the presence of Éclairs milky candy. Hence people clipped with orthodontic wire made of Gold 18K need not hesitate to take Éclairs milky candy orally.

Table 1. Corrosion Parameters of Gold 18K alloy immersed in various test solutions containing artificial saliva (AS) obtained by polarization study.

System	E_{corr} mV/SCE	b_c mV/decade	b_a mV/decade	LPR Ohm·cm^2	I_{corr} A/cm^2
AS	–87	120	307	$4.84 \cdot 10^6$	$7.73 \cdot 10^{-9}$
AS + Éclairs milky candy 500 ppm	–612	124	201	$9.34 \cdot 10^6$	$3.57 \cdot 10^{-9}$

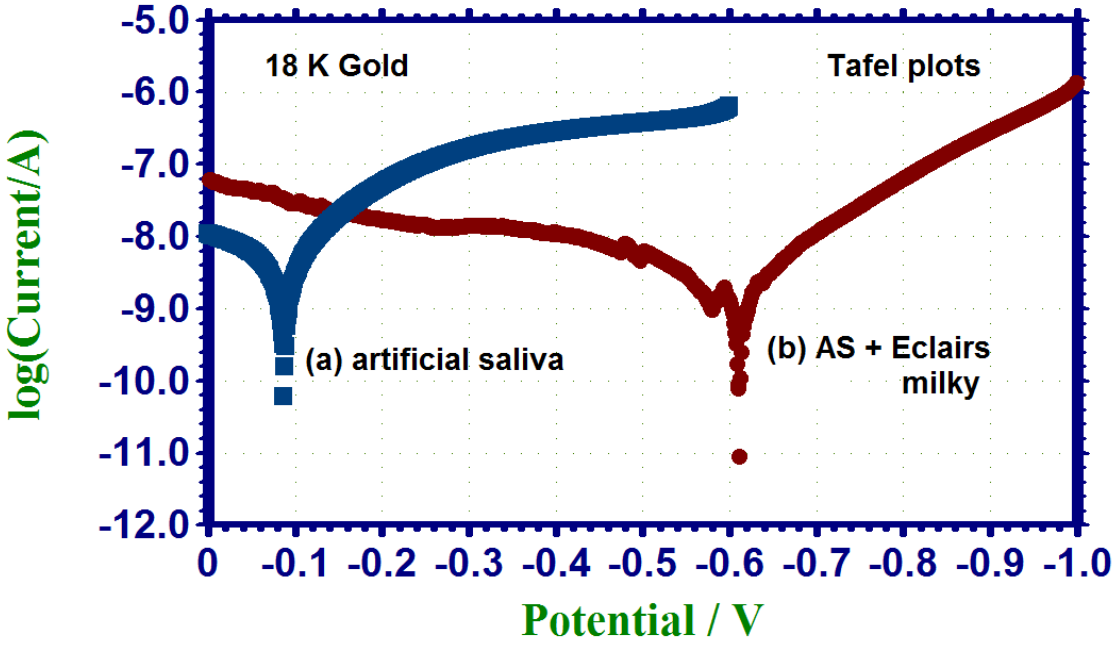


Figure 1. Polarization curves of Gold 18K alloy immersed in various test solutions: (a) artificial saliva; (b) artificial saliva + Éclairs milky candy.

AC Impedance spectroscopy

In the present investigation the same instrument set-up used for polarization study was also used to record AC impedance (EIS) spectroscopy. A time interval of 5 to 10 min was given for the system to attain a steady state open circuit potential. The real part (Z') and imaginary part ($-Z''$) of the cell impedance were measured in Ohms at various frequencies. From Nyquist plot (Figure 2) the values of charge transfer resistance (R_t) and the double layer capacitance (C_{dl}) were calculated. From Bode plots (Figures 3, 4) charge transfer resistance (R_t), impedance value, phase angle value and double layer capacitance (C_{dl}) value were calculated.

The AC impedance spectroscopy of Gold 18K alloy in AS in the absence and presence of 500 ppm of Éclairs milky candy are shown in Figures 2–6. The Nyquist plots are shown in Figure 2. The Bode plots are shown in Figures 3 and 4. The 3D plots are shown in Figures 5 and 6. The corrosion parameters such as charge transfer resistance (R_t), impedance value and double layer capacitance (C_{dl}) values are given in Table 2.

It is observed from Table 2, that in the presence of Éclairs milky candy, the corrosion resistance of Gold 18K alloy in AS increases. This is revealed by the fact that in the presence of Éclairs milky candy, R_t value increases, impedance value increases, phase angle value increases and C_{dl} value decreases (Scheme C). The Interactive 3D Plots are shown in Figures 5 and 6.

Implication

Corrosion resistance of Gold 18K alloy in artificial saliva decreases in the presence of Éclairs milky candy. Hence people clipped with orthodontic wire made of Gold 18K alloy need not hesitate to take Éclairs milky candy orally.

Table 2. Corrosion Parameters of Gold 18K alloy immersed in various test obtained by AC Impedance spectra

System	R_t Ohm·cm^2	C_{dl} F/cm^2	Impedance Log(Z/Ohm)	Phase angle, °
AS	$1.72\cdot10^5$	$2.70\cdot10^{-11}$	5.48	44.68
AS+ Éclairs milky candy 500 ppm	$2.16\cdot10^5$	$2.36\cdot10^{-11}$	5.78	45.00

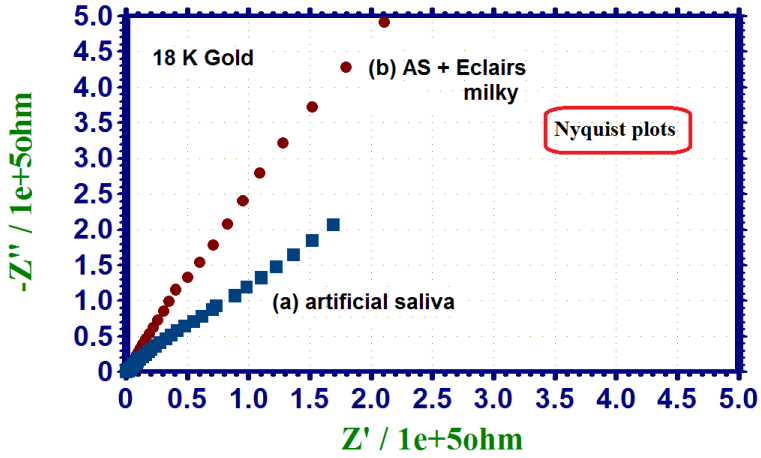


Figure 2. Nyquist plots of Gold 18K alloy immersed in various test solutions: (a) artificial saliva; (b) artificial saliva + Éclairs milky.

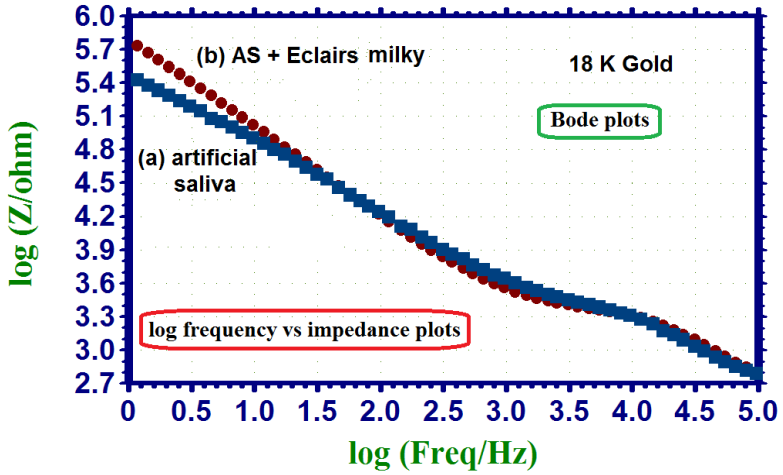


Figure 3. Bode plots of Gold 18K alloy immersed in various test solutions (log frequency *vs* impedance plots): (a) artificial saliva; (b) artificial saliva.

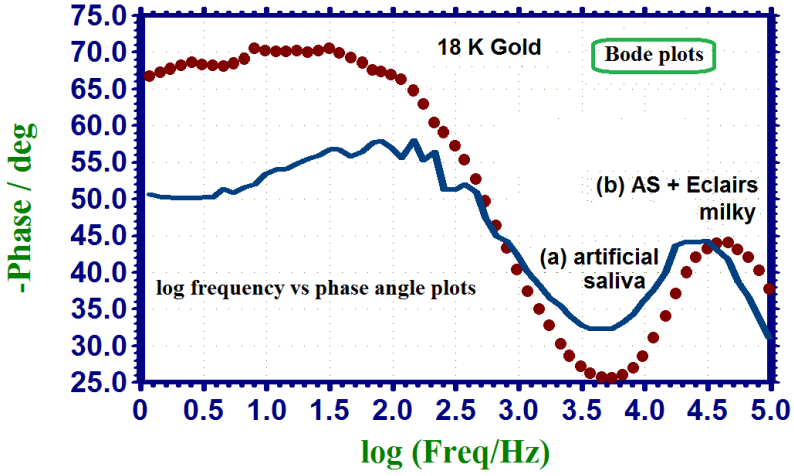
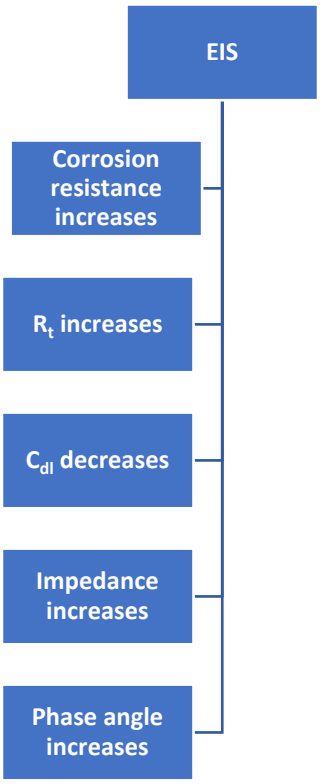


Figure 4. Bode plots of Gold 18K alloy immersed in various test solutions (log frequency *vs* phase angle plots): (a) artificial saliva; (b) artificial saliva.



Scheme C. Comparison of corrosion parameters of AC impedance spectroscopy [Electrochemical Impedance Spectroscopy (EIS)].

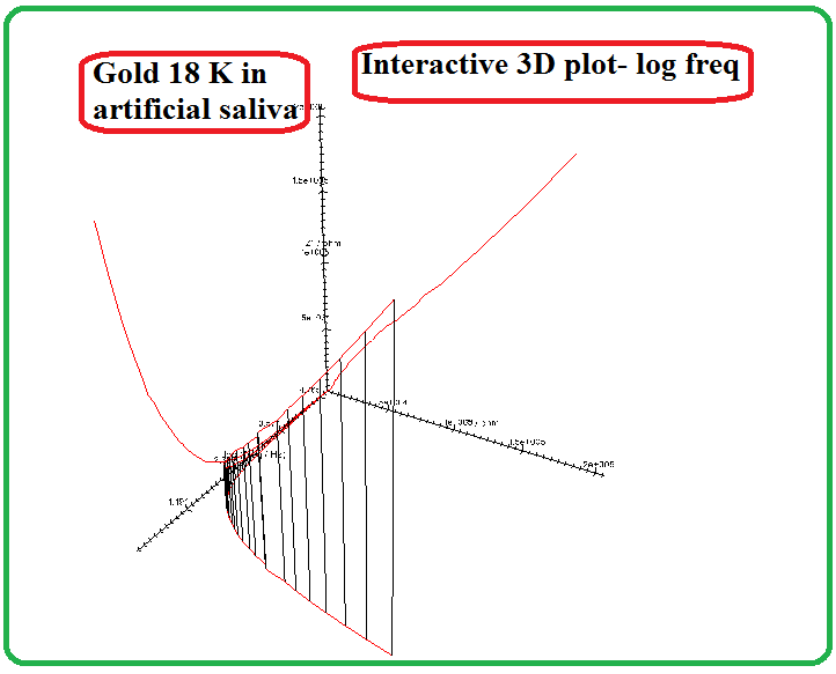


Figure 5. Interactive 3D Plot – log freqгутсн when Gold 18K is immersed in artificial saliva.

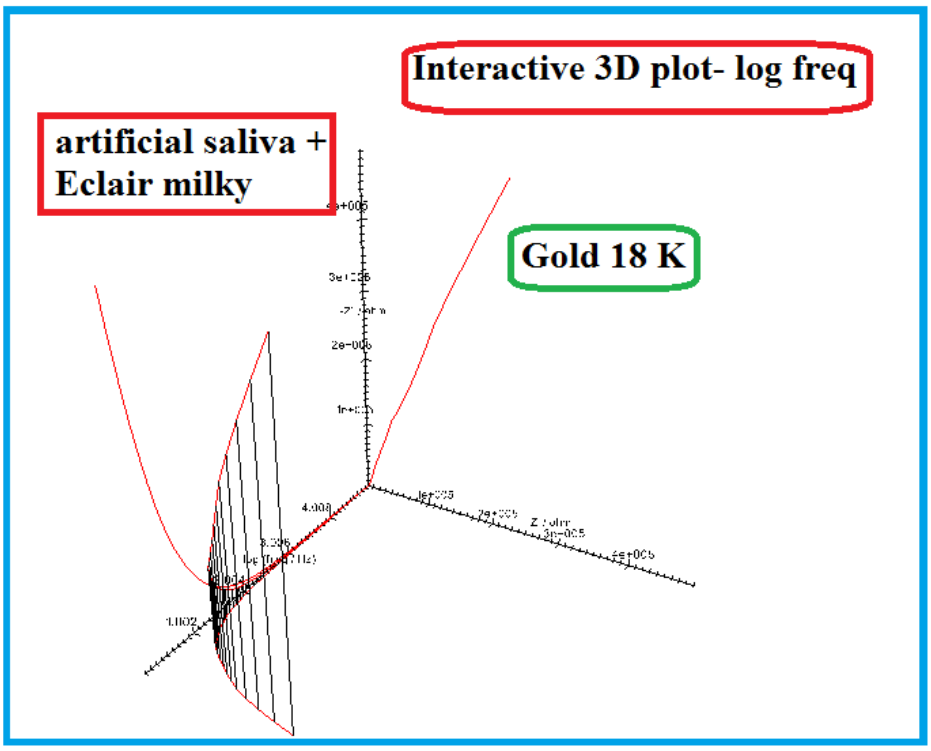


Figure 6. Interactive 3D Plot – log freq when Gold 18K is immersed in artificial saliva + Éclairs milky candy system.

Analysis of AFM images and AFM parameters

Average Roughness (S_a), RMS Roughness (S_q) and Maximum peak to valley height (S_y) (area roughness) of various specimens were calculated. The AFM parameters of (*i*) orthodontic wire made of Gold 18K, (*ii*) orthodontic wire made of Gold 18K immersed in artificial saliva(AS) and (*iii*) orthodontic wire made of Gold 18K, immersed in artificial saliva in the presence of Kopiko candy 500 ppm are given in Table 3. The corresponding images are shown in Figures 7–9.

Table 4. AFM parameters of Gold 18K immersed in various test solutions.

Details	Average Roughness (S_a) (nm)	RMS Roughness (S_q) (nm)	Maximum peak – valley height (S_y)
Polished Gold 18K	267.01	329.68	2735.4 nm
Polished Gold 18K in AS	449.53	538.54	3.26 µm
Polished Gold 18K in AS + Éclairs milky candy	65.62	86.04	878.61 nm

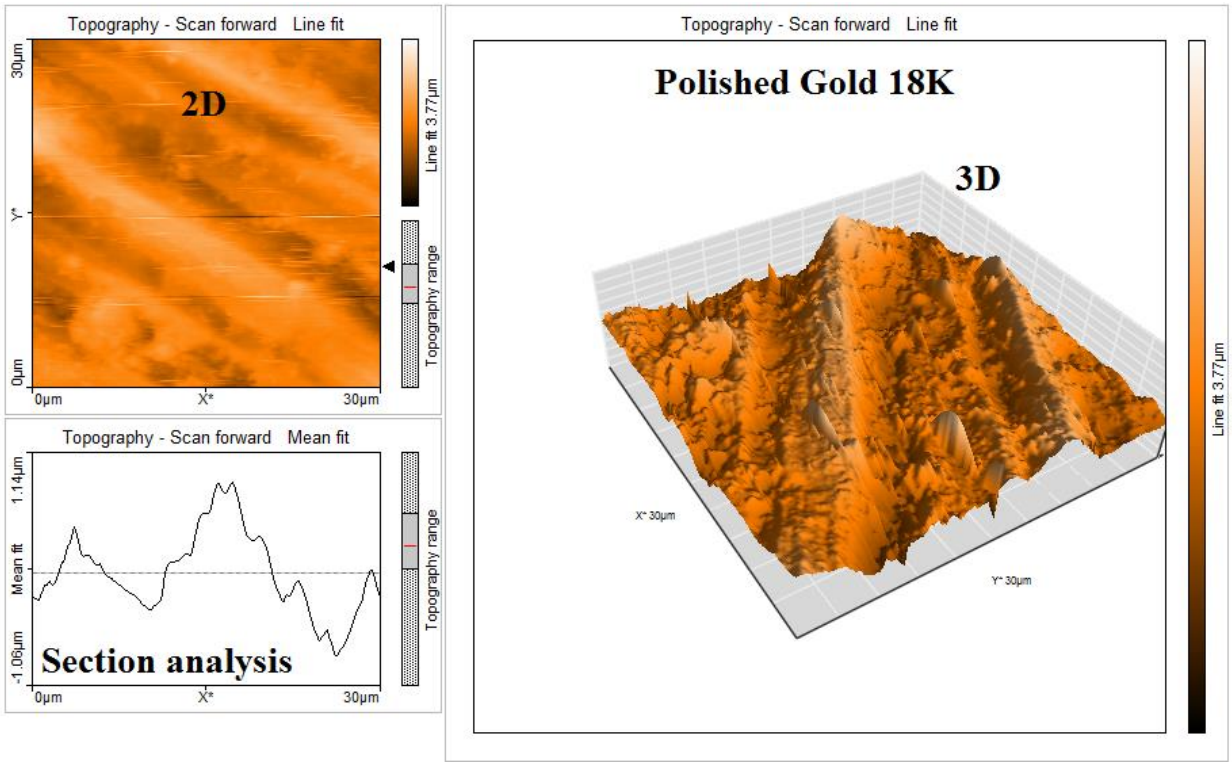


Figure 7. AFM images of polished Gold 18K in artificial saliva.

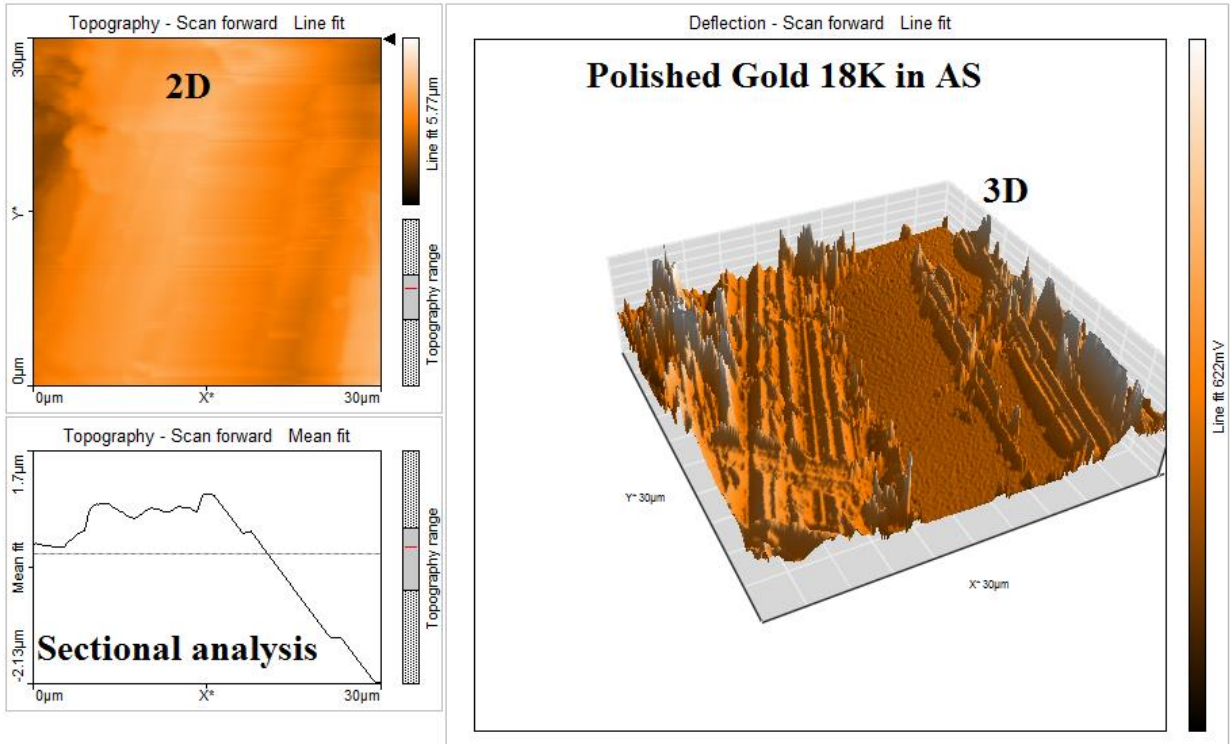


Figure 8. AFM images of polished Gold 18K.

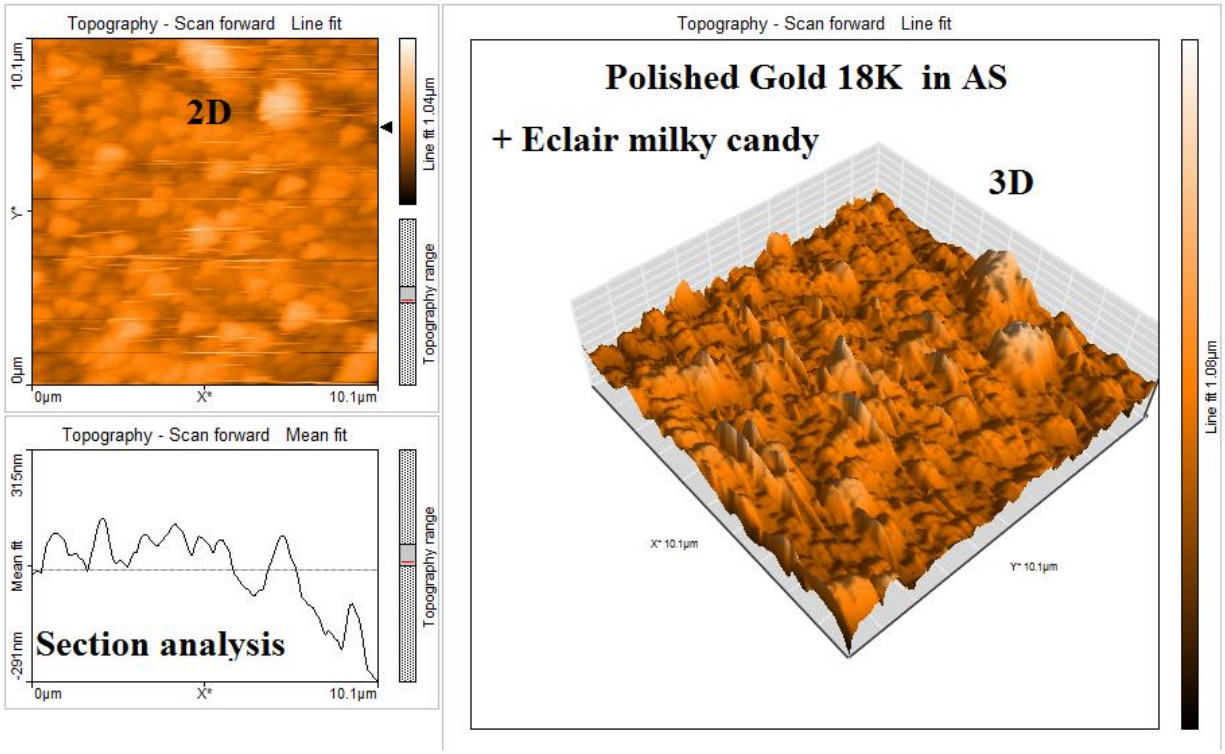


Figure 9. AFM images of polished Gold 18K in AS + Éclairs milky candy.

It is inferred from Table 3, that

(i) for Polished Gold 18K in AS + Éclairs milky candy, the AFM parameters are very low. This is due to the smoothness of the protective formed on Gold 18K surface.

(ii) for Polished Gold 18K in AS the AFM parameters are very high. This is due to the formation of corrosion products on Gold 18K surface.

(iii) for Polished Gold 18K system the AFM parameters are in between those of the two systems.

Summary and Conclusions

Outcome of the study

Corrosion resistance of Gold 18K alloy in artificial saliva (AS), in the absence and presence of Éclairs milky candy has been investigated by polarization study and AC impedance spectroscopy (Table 3). It is inferred that the corrosion resistance of Gold 18K alloy in artificial saliva increases in the presence of Éclairs milky candy. This is revealed by an increase in LPR value, an increase in R_t value, an increase in impedance value, a decrease in corrosion current, and a decrease in double layer capacitance value. Hence it implies that people clipped with orthodontic wire made of Gold 18K alloy need not hesitate to take Éclairs milky candy orally.

Table 3. Summary of the findings – Gold 18K immersed in artificial saliva.

System	Artificial saliva	AS + Éclairs milky	Inference
Corrosion potential	–87	–612	Cathodic shift
LPR	$4.84 \cdot 10^{6}$	$9.34 \cdot 10^{6}$	Increases
Corrosion current	$7.73 \cdot 10^{-9}$	$3.57 \cdot 10^{-9}$	Decreases
R_t, Ohm·cm^2	$1.72 \cdot 10^{5}$	$2.16 \cdot 10^{5}$	Increases
Impedance log(Z/ohm)	5.48	5.78	Increases
C_{dl}, F/cm^2	$2.70 \cdot 10^{-11}$	$2.36 \cdot 10^{-11}$	Decreases
Phase angle, °	44.68	45.00	Increases

References

1. J. Kamiński, K. Małkiewicz, J. Rębiś and T. Wierzchoń, The effect of glow discharge nitriding on the corrosion resistance of stainless steel orthodontic arches in artificial saliva solution, *Arch. Metall. Mater*., 2020, **65**, 375–384. doi: 10.24425/amm.2020.131740
2. E. Erwansyah and C. Susilowati, The effect of snake fruit extract (*Salacca zalacca*) in inhibiting the release of chromium (Cr) and nickel (Ni) ion from stainless steel orthodontic wire to saliva, *Int. J. Appl. Pharm*., 2019, **11**, 33–36. doi: 10.22159/ijap.2019.v11s4.35286
3. I.M. Trolic, N.L. Serdarevic, Z. Todoric, A. Budimir, S. Spalj and H.O. Curkovic, Corrosion of orthodontic archwires in artificial saliva in the presence of *Lactobacillus reuteri*, *Surf. Coat. Technol*., 2019, **370**, 44–52. doi: 10.1016/j.surfcoat.2019.04.081
4. N. Simionescu, A. Ravoiu and L. Benea, Electrochemical *in vitro* properties of 316L stainless steel for orthodontic applications, *Rev. Chim. (Bucharest, Rom.)*, 2019, **70**, 1144–1148. doi: 10.37358/RC.19.4.7081
5. M.F. Khamis and K.A.A. Jabar Almakzomi, Antibacterial, antifungal and anticorrosion studies for the effect of hydroxyapatite coating on an orthodontic alloy, *Int. J. Corros. Scale Inhib*., 2023, **12**, no. 1, 205–214. doi: 10.17675/2305-6894-2023-12-1-12
6. A. Anandan, S. Rajendran, J. Sathiyabama and D. Sathiyaraj, Influence of some tablets on corrosion resistance of orthodontic wires made of SS 316L alloy in artificial saliva, *Int. J. Corros. Scale Inhib*., 2017, **6**, 132–141. doi: 10.17675/2305-6894-2017-6-2-3
7. R. D'souza, A. Chattree and S. Rajendran, Corrosion Resistance of SS 316L alloy in Artificial Saliva in presence of Sparkle fresh Toothpaste, *Port. Electrochim. Acta*, 2017, **35**, 339–350. doi: 10.4152/pea.201706339
8. V. Agnes Brigitta, C. Thangavelu and S. Rajendran, Corrosion resistance of SS18/8, Gold 18 carat, Gold 22 carat and SS 316L alloy in artificial saliva in the absence and presence of Vitavion Fort tablet 500mg, *Eur. J. Biomed. Pharm. Sci*., 2018, **5**, 864–871.

9. R. Saranya and S. Rajendran, Influence of D-glucose on corrosion resistance of SS 316L in presence of artificial saliva, *Rasayan J. Chem*., 2018, **11**, 103–110. doi: 10.7324/RJC.2018.1111747
10. M. Zhang, Y. Yang, C. Song, Y. Bai and Z. Xiao, Effect of the heat treatment on corrosion and mechanical properties of CoCrMo alloys manufactured by selective laser melting, *Rapid Prototyping J*., 2018, **24**, no. 7, 1235–1244. doi: 10.1108/rpj-10-2017-0215
11. S. Gowri, B. Jaslin Lara, B. Kanagamani, A. Kavitha, A.M. Belciya, C. Muthunayaki, C. Pandeeswari, J.M. Praveena, T. Umasankareswari, L.J. Majellah and S. Rajendran, Influence of Metformin Hydrochloride – 250 mg (MFH) tablet on Corrosion Resistance of orthodontic wire made of NiCr alloy in Artificial Saliva, *J. Chem. Sci. Chem. Eng*., 2020, **1**, no. 1, 1–10. doi: 10.47890/JCSCE/SRAJENDRAN/2020/10082111
12. D.R. Nahusona and P. Koriston, The effectiveness of watermelon rind extract as corrosion inhibitor in stainless steel orthodontic wire, *Int. J. Appl. Pharm*., 2019, **11**, no. 4, 22–25. doi: 10.22159/ijap.2019.v11s4.35283
13. P. Shanthy, J.A. Thangakani, S. Karthika, S. Rajendran and J. Jeyasundari, Corrosion inhibition by an aqueous extract of *Ervatamia divaricata*, *Int. J. Corros. Scale Inhib*., 2021, **10**, no. 1, 331–348. doi: 10.17675/2305-6894-2021-10-1-19
14. S.J.H.M. Jessima, A. Berisha, S.S. Srikandan and S. Subhashini, Preparation, characterization, and evaluation of corrosion inhibition efficiency of sodium lauryl sulfate modified chitosan for mild steel in the acid pickling process, *J. Mol. Liq*., 2020, **320**, 114382. doi: 10.1016/j.molliq.2020.114382
15. M.E. Belghiti, Y.E. Ouadi, S. Echihi, F. Bentiss and A. Dafali, Anticorrosive properties of two 3,5-disubstituted-4-amino-1,2,4-triazole derivatives on copper in hydrochloric acid environment: Ac impedance, thermodynamic and computational investigations, *Surf. Interfaces*, 2020, **21**, 100692. doi: 10.1016/j.surfin.2020.100692
16. A.S. Prabha, K. Kavitha, H.B. Shrine and S. Rajendran, Inhibition of corrosion of mild steel in simulated oil well water by an aqueous extract of *Andrographis paniculata*, *Indian J. Chem. Technol*., 2020, **27**, no. 6, 452–460.
17. J.J.M. Praveena, J.A. Clara, S. Rajendran and A.J. Amalraj, Inhibition of corrosion of mild steel in well water by an aqueous extract of soapnut (*SapindusTrifoliatus*), *Mater. Prot*., 2021, **62**, no. 4, 277–290. doi: 10.5937/zasmat2104277P
18. V.D.A.M. Jeslina, S.J. Kirubavathy, A. Al-Hashem, R.M. Joany and C. Lacnjevac, Inhibition of corrosion of mild steel by an alcoholic extract of a seaweed *Sargassum muticum*, *Mater. Prot*., 2021, **62**, no. 4, 304–315. doi: 10.5937/zasmat2104304J
19. S.Y. Al-Nami and A.E.-A.S. Fouda, Corrosion inhibition effect and adsorption activities of methanolic myrrh extract for cu in 2 M HNO_3, *Int. J. Electrochem. Sci*., 2020, **15**, no. 2, 1187–1205. doi: 10.20964/2020.02.23

20. A. Christy Catherine Mary, J. Jeyasundari, V.R. NazeeraBanu, S.S. Kumaran and A. Peter Pascal Regis, Corrosion behavior of orthodontic wires in artificial saliva with presence of beverage (Book Chapter), *Nanotechnology in the Beverage Industry: Fundamentals and Applications*, 2020, 471–504.
21. S.C. Joycee, A.S. Raja, A.S. Amalraj and S. Rajendran, Inhibition of corrosion of mild steel pipeline carrying simulated oil well water by *Allium sativum* (Garlic) extract, *Int. J. Corros. Scale Inhib*., 2021, **10**, no. 3, 943–960. doi: 10.17675/2305-6894-2021-10-3-8
22. R. Dorothy, T. Sasilatha and S. Rajendran, Corrosion resistance of mild steel (Hull plate) in sea water in the presence of a coating of an oil extract of plant materials, *Int. J. Corros. Scale Inhib*., 2021, **10**, no. 2, 676–699. doi: 10.17675/2305-6894-2021-10-2-13
23. A. El Yadini, H. Saufi, E. Perez, M. Blanzat, S. Franceschi-Messant and S. El Hajjaji, Synthesis and characterization of bolaform surfactants from sugar derivative and their associates with 2-aminobenzomidazole as inhibitor of zinc in 3% NaCl medium, *Int. J. Corros. Scale Inhib*., 2023, **12**, no. 1, 32–47. doi: 10.17675/2305-6894-2023-12-1-2
24. N.A. Abdul-Rida, M.H. Sayyah and Q.A.H. Jaber, Synthesis, characterization, efficiency evaluation of some novel triazole derivatives as acid corrosion inhibitors, *Int. J. Corros. Scale Inhib*., 2023, **12**, no. 1, 101–125. doi: 10.17675/2305-6894-2023-12-1-6
25. T. Raja, S.S. Syed Abuthahir, A. Samsath Begum, M. Lavanya and S. Rajendran, Corrosion inhibition performance of carbon steel in 1 N hydrochloric acid by an aqueous extract of *Syzygium cumini Linn* (SCL) plant leaves, *Int. J. Corros. Scale Inhib*., 2022, **11**, no. 4, 1819–1838. doi: 10.17675/2305-6894-2022-11-4-26
26. A.A. Kruzhilin, D.S. Shevtsov, D.V. Lyapun, A.Yu. Potapov, Kh.S. Shikhaliev, O.A. Kozaderov, D.Yu. Vandyshev and V.B. Sulimov, 3-Alkylsulfonyl-5-amino-1,2,4-triazoles – new corrosion inhibitors of copper and copper-containing alloys, *Int. J. Corros. Scale Inhib*., 2022, **11**, no. 4, 1703–1715. doi: 10.17675/2305-6894-2022-11-4-19
27. A. Nilavan, B. Sathiyaprabha, S.V.A. Ratthika, S.J.J.P. Seeli, A.J. Sindhuja, S. Rakshana, A.M. Princy and S. Rajendran, Influence of a Show Case Polish Coating on Corrosion Resistance of Mild Steel in Simulated Concrete Pore Solution, *Orient. J. Phys. Sci*., 2022, **7**, no. 1, 16–25. doi: 10.13005/OJPS07.01.03

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