Wilfred Dennis Antony[1], Rajendran Maria Joany[2], Rajendran Dorothy[3], Satha Sivam Susithra[4], Màriya Lurthu Raj Lavanya[4], Kuppusamy Bhuvaneswari[4], Xavier Joseph Susmitha[4], Nilavan Anitha[4], Susai Rajendran[4,5], Caslav Lacnjevac[6]*

[1]St John's Public School, Medavakkam, Chennai, India, [2]Sathyabama Institute of Science and Technology (Deemed to be University), Department of ECE, Chennai, India, [3]AMET University, Department of EEE, Chennai, India, [4] Department of Chemistry, Corrosion Research Centre , St. Antony's College of Arts and Sciences for Women, Dindigul-624005, (Affiliated to Mother Teresa Women's University, Kodaikanal) India. [5]Pondicherry University, Centre for Nanoscience and Technolgy , Puducherry, India, [6]Faculty of Agriculture, University of Belgrade, Serbia

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Influence of a candy on the corrosion resistance of orthodontic wire made of Gold 18K in the presence of artificial saliva

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 Éclairschocolate candy has been investigated by potentiodynamic polarization study and electrochemical impedance spectra (EIS). It is observed that corrosion resistance of Gold 18K alloy immersed in artificial saliva in the presence of 500 ppm of Éclairs chocolate candy increases. Hence it is concluded that people clipped with orthodontic wire made of Gold 18K alloy need not worry about taking Éclairs chocolate candy orally. When Gold 18K alloy is immersed in artificial saliva in the presence of 500 ppm of Éclairs chocolate candy, Linear Polarisation Resistance (LPR) value increases from 4844947 Ohmcm^2 to 35700904 Ohmcm^2; corrosion current decreases from 7.726x10^{-9}A/cm^2 to 1.350x10^{9}A/cm^2; charge transfer resistance value(R_t) increases from 172100 Ohmcm^2 to 398800 Ohmcm^2; impedance value increases from 5.445 to 5.975; double layer capacitance decreases from 2.963x10^{-11}F/cm^2 to 1.1279x10^{-11}F/cm^2, and phase angle increases from 44.68° to 48.23°.

Keywords: *Corrosion resistance, Gold 18K alloy, Artificial saliva, Éclairschocolate candy, potentiodynamic polarization study, electrochemical impedance spectra (EIS), pediatric dentistry.*

1. INTRODUCTION

Dentists make use of various types of alloys such as SS 18/8, 316 L, Thermo active alloy etc., to regulate the growth of teeth, After having clipped with the orthodontic wires, people orally take a lot of food items such as milk, soft drinks, juices, and tablets. During these intakes orally, the orthodontic wires may undergo corrosion apart from the corrosion due to their presence in the oral environment, namely saliva. Many scientists are doing research work in this line, measuring the corrosion resistance of wires in saliva and also in presence of food additives and tablets orally taken.

Zhang et al. have investigated the effect of the heat treatment on corrosion and mechanical properties of CoCrMo alloys manufactured by selective laser melting. Their work presents the adhesion properties of *Streptococcus* mutants on the surface of CoCrMo alloys manufactured by selective laser melting (SLM) and proposes how to regulate the effect of the heat treatment on the corrosion resistance and mechanical properties of CoCrMo alloys manufactured by SLM [1] Li et al. have investigated the effect of fluoride on the corrosion behavior of nanostructured Ti-24Nb-4Zr-8Sn alloy in acidulated artificial saliva by electrochemical studies, such as potentiodynamic polarization and electrochemical impedance spectroscopy (EIS) have been used to evaluate the corrosion resistance of the said alloy. The protective film has been analyzed by SEM and X-ray photoelectron spectroscopy (XPS). The study reveals that the superior corrosion resistance of the NS Ti2448 alloy as well as lower pitting sensitivity

Corresponding author: Wilfred Dennis Antony
E-mail: susairajendran@gmail.com
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and higher tolerance to fluoride due mostly to grain refinement [2]. Electrochemical behavior of two dental alloys: palladium alloy (Palidor) and Ni-Cr alloy (Verasoft) in three types of artificial saliva has been investigated by Pendefunda et al. by linear and cyclic polarization curves. It has been reported that metallic dental restorations are eternally affected by the factors of the oral environment [3]. Polarization studies have been conducted to investigate the bio-corrosion behavior of Zr39.5Cu50.5Ag4Ti6 metallic glass by Kumar et al.[4]. The experiment was conducted in various simulated artificial body conditions such as artificial saliva solution, phosphate-buffered saline solution, artificial blood plasma solution, and Hank's balanced saline solution. The bio-corrosion results of metallic glass were compared with traditional biomaterials. The study has provided bio-compatible properties of Zr39.5Cu50.5Ag4Ti6 metallic glass [4]. Corrosion performance of Co-Cr dental alloys processed by alternative CAD/CAM technologies in artificial saliva solutions has been investigated by Savencu et al. Electrochemical studies such as polarisation study, AC impedance spectra, and cyclic voltammetry have been employed to note the corrosion resistance of materials and investigation. Computer-assisted processing technologies revealed hopeful results, representing a good alternative to traditional manufacturing methods for metallic frameworks for dental prostheses [5]. Dimic et al., have estimated the electrochemical behavior and biocompatibility of ultrafine-grained (UFG) commercially pure titanium (CPTi) and Ti–13Nb–13Zr (TNZ) alloy obtained by high-pressure torsion process. The electrochemical behavior of materials in artificial saliva at 37°C was evaluated by potentiodynamic polarization tests and electrochemical impedance spectroscopy (EIS). The results showed that UFG TNZ alloy showed better corrosion resistance [6]. Renita D'Souza et al. have studied the corrosion resistance of SS 316L alloy in Artificial Saliva in presence of Sparkle Fresh Toothpaste, by electrochemical studies [7]. Agnes Brigitta et al. have investigated corrosion resistance of SS18/8, Gold18 carat, Gold 22 carat, and SS 316L alloy in the artificial saliva in the absence and presence of VitavionFort Tablet 500mg [8]. The influence of D-glucose on corrosion resistance of SS 316L in presence of artificial saliva has been studied by Saranya and Rajendran by making use of electrochemical studies [9]. Kamiński et al. have investigated the effect of glow discharge nitriding on the corrosion resistance of stainless steel orthodontic arches in artificial saliva solution [10]. They have carried out a comparative study on orthodontic arch-wires AISI 304 steel before and after low temperature plasma nitriding. Polarisation study and AC impedance spectra have been employed for this purpose [10].

The present work is undertaken to study the corrosion resistance of orthodontic wire made of 18K Gold in the artificial saliva in the presence of Éclairs chocolate choco candy (500 ppm). Electrochemical studies such as potentiodynamic polarisation study and electrochemical impedance spectra (EIS) have been employed to measure the corrosion resistance.

2. EXPERIMENTAL

Gold 18 karat

Caratage' is the measurement of purity of gold alloyed with other metals. 24 carat is pure gold with no other metals. Lower caratages contain less gold; 18 carat gold contains 75 per cent gold and 25 per cent other metals, often copper or silver. The metal specimens were encapsulated in Teflon. The metal specimens were polished to mirror finish and degreased with trichloroethylene. The metal specimens were immersed in artificial saliva.

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. Éclairs chocolate candy (500 ppm) was used in the present study.

Potentiodynamic polarization study

A CHI 660A workstation model was used in the electrochemical studies. Potentiodynamic polarization study was carried out using a three-electrode cell assembly. Gold 18 Karat 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.

Electrochemical impedance spectra (EIS)

Electrochemical impedance spectra (EIS) were recorded in the same instrument used for potentio-dynamic 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. R_t was calculated from the relation: $R_t = (R_t + R_s) - R_s$, where R_s is the solution resistance. C_{dl} was calculated from the relation, $C_{dl} = 1/2\pi R_t f_{max}$ where f_{max} is the maximum frequency.

3. RESULTS AND DISCUSSION

The influence of choco candy (500 ppm) on corrosion resistance of Gold 18K alloy in artificial saliva (AS), has been investigated by potentiodynamic polarization study and electrochemical impedance spectra (EIS) [11–26]. When corrosion resistance increases, linear polarization resistance increases, charge transfer resistance (R_t) increases and impedance value increases. On the other hand, corrosion current decreases and double layer capacitance decreases.

Potentiodynamic polarization study

The potentiodynamic polarization curves of Gold 18K alloy in artificial saliva (AS) in the absence and presence of 500 ppm of Éclairs choco candy are shown in Figure 1. The corrosion parameters are given in Table 1 and Figure 4. It is observed from Table 1 that in the presence of Gold 18K, the corrosion resistance of Gold 18K alloy in AS increases. This is revealed by the fact that, in the presence of choco candy, linear polarization resistance (LPR) value of Gold 18K alloy increases Figures 1 and 2) and corrosion current decreases. It is also observed that in the presence of choco candy the corrosion potential shifts from -87 to –476 mV vs. SCE (Figures 1 and 2). It is inferred that in the presence of choco candy the cathodic reaction is controlled predominatly. The candy behaves as cathodic type inhibitor.

Implication

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

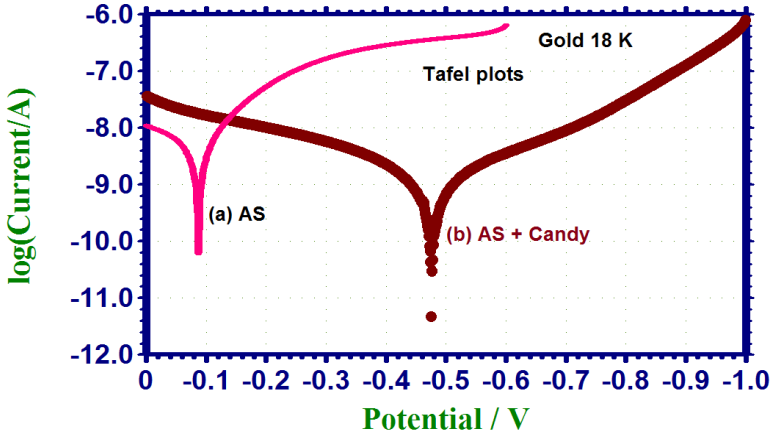

Figure 1. Potentiodynamic polarisation curves of Gold 18K alloy immersed in various test solutions: (a)AS; (b)AS + Candy

Slika 1.Potenciodinamičke polarizacione krive legure zlata 18K uronjene u različite test rastvore: (a)AS; (b) AS + Candi

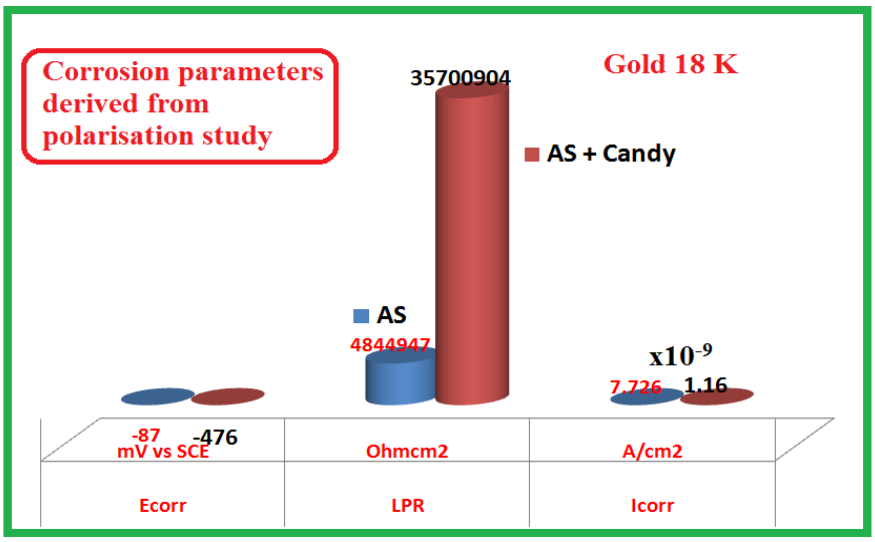

Figure 2. Comparison of corrosion parameters derived from potentiodynamic polarization study

Slika 2. Poređenje parametara korozije izvedenih iz studije potenciodina mička polarizacije

Table 1. Corrosion Parameters of Gold 18K immersed in various test solutions obtained by potentiodynamic polarisation study

Tabela 1. Parametri korozije zlata 18K uronjenog u različite test rastvore dobijene potenciodinamičkim studijama polarizacije

System	Ecorr mV vs SCE	bc mV/decade	ba mV/decade	LPR Ohmcm^2	Icorr A/cm^2
AS	-87	119	307	4844947	7.726 x10-9
AS + Candy	-476	190	190	35700904	1.160 x10-9

Electrochemical impedance spectra (EIS)

From electrochemical impedance spectra (EIS) two types of plots are obtained. They are Nyquist plots and Bode plots. From Nyquist plot the values of charge transfer resistance (R_t) and the double layer capacitance (C_{dl}) were calculated. From Bode plots charge transfer resistance (R_t), impedance value , phase angle value and double layer capacitance (C_{dl}) value were calculated. The electrochemical impedance spectra (EIS) of Gold 18K alloy in AS in the absence and presence of 500 ppm of choco candy are shown in Figures 3-6. The Nyquist plots are shown in Figure 3. The Bode plots are shown in Figures 4 and 5. 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 choco candy, the corrosion resistance of Gold 18K alloy in AS increases. This is revealed by the fact that in the presence of choco candy, R_t value increases (Figure 7), impedance value increases, phase angle value increases and C_{dl} value decreases (Figures 3-7).

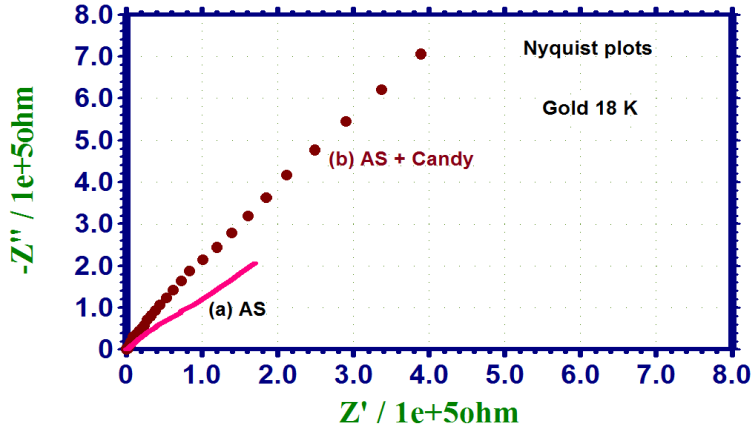

Figure 3. Nyquist plots of Gold 18K alloy immersed in various test solutions: (a) AS; (b) AS + Candy

Slika 3. Nyquist-ovi dijagrami legure zlata 18K uronjeni u različita test rešenja: (a) AS; (b) AS + Candi

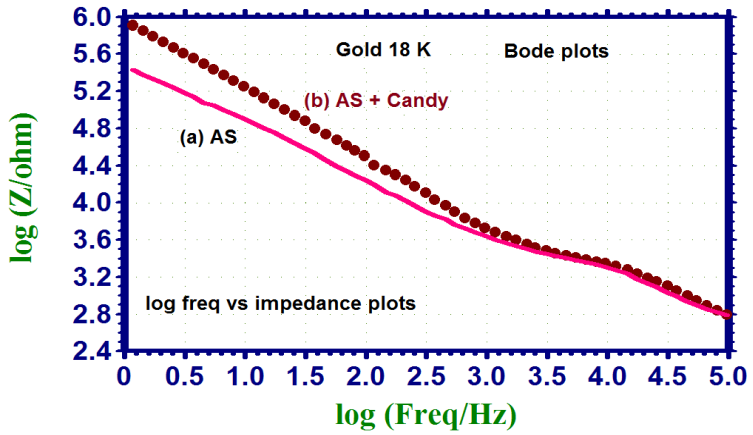

Figure 4. Bode plots (log freq vs impedance plots) of Gold 18K alloy immersed in various test solutions: (a) AS; (b) AS + Candy

Slika 4. Bode-ovi dijagrami (grafikoni log frekvencije u odnosu na impedansu) legure zlata 18K uronjene u različita testna rešenja: (a) AS; (b) AS + Candi

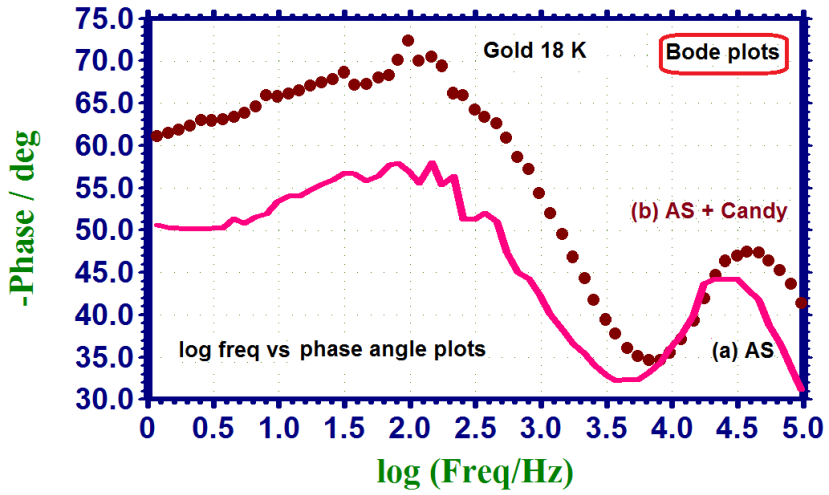

Figure 5. Bode plots (log freq vs phase angle plots) of Gold 18K alloy immersed in various test solutions: (a) AS; (b) AS + Candy

Slika 5. Bode-ovi dijagrami (grafikoni log frekvencije u odnosu na fazni ugao) legure zlata 18K uronjene u različita test rešenja: (a) AS; (b) AS + Candi

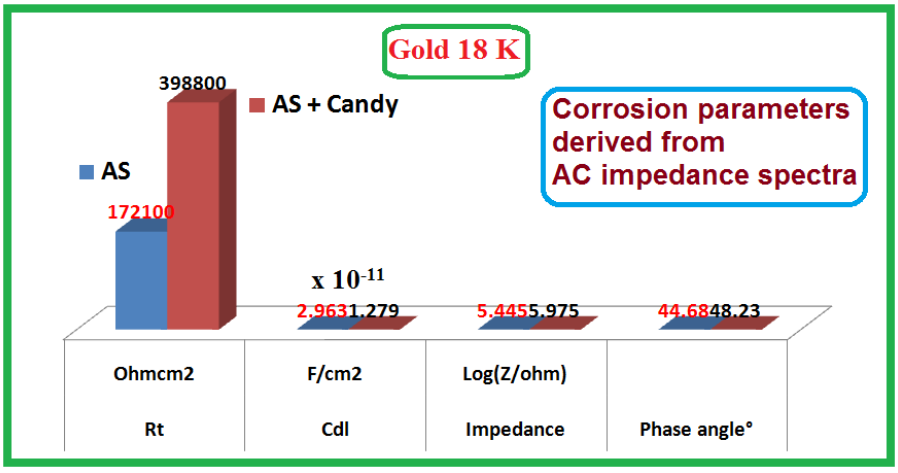

Figure 6. Comparison of corrosion parameters derived from electrochemical impedance spectra (EIS)

Slika 6. Poređenje parametara korozije izvedenih iz spektra elektrohemijske impedanse (EIS)

Table 2. Corrosion Parameters of Gold 18K immersed in various test solutions obtained by electrochemical impedance spectra (EIS)

Tabela 2. Parametri korozije zlata 18K uronjenog u različite test rastvore dobijene spektrom elektrohemijske impedanse (EIS)

System	R_t Ohmcm^2	C_{dl} F/cm^2	Impedance Log(Z/ohm)	Phase angle°
AS	172100	2.963 x 10^{-11}	5.445	44.68
AS + Candy	398800	1.279x 10^{-11}	5.975	48.23

Implication

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

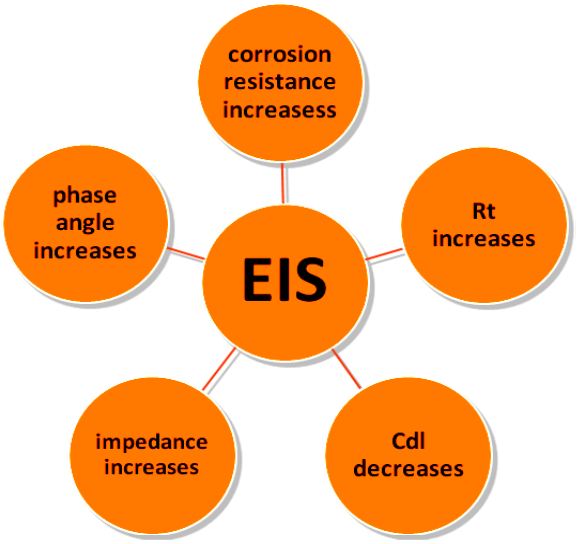

Figure 7. Comparison of corrosion parameters of Electrochemical Impedance Spectra (EIS)

Slika 7. Poređenje parametara korozije spektra elektrohemijske impedanse (EIS)

4. SUMMARY AND CONCLUSIONS

Outcome of the study

Corrosion resistance of Gold 18K alloy alloy in artificial saliva (AS), in the absence and presence of Éclairs choco candy has been investigated by potentiodynamic polarization study and electro-chemical impedance spectra (EIS). It is inferred that the corrosion resistance of Gold 18K alloy alloy in artificial saliva increases in the presence of Éclairs choco candy. This is revealed by a increase in linear polarization resistance (LPR) value, an increase in charge transfer resistance (R_t) value, an increase in impedance value, a decrease in corrosion current, and a decrease in double layer capacitance value. This is due to the adsorption of the active ingredients present in the chocolate such as glucose, sugar on the gold surface to form a protective film. Hence it implies that people, especially children, clipped with orthodontic wire made of Gold 18 K alloy alloy need not hesitate to take Éclairs choco candy orally.

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IZVOD

UTICAJ BOMBONA NA OTPORNOST NA KOROZIJU ORTODONTSKE ŽICE OD ZLATA 18K U PRISUSTVU VEŠTAČKE PLJUVAČKE

Otpornost na koroziju ortodontske žice napravljene od legure zlata 18K uronjene u veštačku pljuvačku u odsustvu i prisustvu 500 ppm čokoladnih bombona ispitana je potenciodinamičkom polarizacionom studijom i spektrom elektrohemijske impedanse (EIS). Primećeno je da se povećava otpornost na koroziju legure zlata 18K uronjene u veštačku pljuvačku u prisustvu 500 ppm čokoladnih bombona. Otuda se zaključuje da ljudi koji imaju ošišani ortodontsku žicu od legure zlata 18K u ustima ne moraju da brinu o uzimanju čokoladnih bombona. Kada se legura zlata 18K uroni u veštačku pljuvačku u prisustvu 500 ppm čokoladnih bombona, vrednost linearne polarizacione otpornosti (LPR) se povećava sa 4844947 Ohmcm^2 na 35700904 Ohmcm^2; struja korozije se smanjuje sa 7,726x10^{-9}A/cm^2 na 1,350x10^{-9}A/cm^2; vrednost otpora prenosa naelektrisanja (Rt) raste sa 172100 Ohmcm^2 na 398800 Ohmcm^2; vrednost impedanse se povećava sa 5,445 na 5,975; kapacitivnost dvostrukog sloja se smanjuje sa 2,963 x10^{-11}F/cm^2 na 1,1279 x10^{-11}F/cm^2, a fazni ugao se povećava sa 44,68° na 48,23°.

Ključne reči: *otpornost na koroziju, legura zlata 18K, veštačka pljuvačka, čokoladna bombona, potenciodinamička studija polarizacije, spektri elektrohemijske impedanse (EIS), pedijatrijska stomatologija.*

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