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Corrosion resistance of SS 18/8 alloy and Gold 22 K alloy in artificial sweat in the presence of D-Glucose

ABSTRACT

Corrosion resistance of SS 18/8 alloy and Gold 22 K alloy immersed in artificial sweat in the absence and presence of 100 ppm of D-Glucose has been investigated by polarization study and AC impedance spectra. It is observed that corrosion resistance of SS 18/8 alloy and also Gold 22 K alloy immersed in artificial sweat in the presence of 100 ppm of D-Glucose decreases. Hence it is concluded that people wearing ornaments made of these two alloys need to worry about the excess of D-Glucose in their sweat. When SS 18/8 alloy is immersed in artificial sweat in the presence of 100 ppm of D-Glucose, Linear Polarisation Resistance value decreases from 589308032 Ohmcm^2 to 87905 Ohmcm^2 ; corrosion current increases from 8.923x10^{-11}A/cm^2 to 4.008x10^{-9} A/cm^2; charge transfer resistance value increases from 4884 Ohmcm^2 to 3.168 x10^{-7} 12210 Ohmcm^2; impedance value decreases from 8.023 to 4.008; double layer capacitance increases from 8.9099x10^{-14}F/cm^2 to 1.4868 x10^{-9}F/cm^2, and phase angle decreases from 94° to 54°. When Gold 22 K alloy is immersed in artificial sweat in the presence of 100 ppm of D-Glucose, Linear Polarisation Resistance value decreases from 4248438 Ohmcm^2 to 236576 Ohmcm^2 ; corrosion current increases from 8.038 x10^{-9}A/cm^2 to 1.546 x10^{-7}A/cm^2 ; charge transfer resistance decreases from 23680 Ohmcm^2 to 6336 Ohmcm^2; impedance value decreases from 4.647to 4.567; double layer capacitance increases from 2.154 x10^{-10} F/cm^2 to 8.049x10^{-10} F/cm^2 , and phase angle increases from 66° to 64°.

Keywords: *Corrosion resistance, SS 18/8 alloy ,Gold 22 K alloy , Artificial sweat , D-Glucose, polarization study , AC impedance spectra.*

1. INTRODUCTION

Human perspiration fluid with a relatively high chloride ions content (~ 0.14 M) comes in contact with a number of consumer products resulting in a variety of undesirable effects such as malfunction and corrosion. In jewelry many alloys are used to make ornaments such as rings, bangles, wrist watches, earrings, nose rings etc., When these materials come in contact with sweat they undergo corrosion. Several research papers have been published in this regard [1-10]. Degradation response and bioactivity assessment of antimicrobial copper coatings in simulated hand sweat environment have been investigated by Bharadishettar and Udaya Bhat [1]. The degradation behavior of coatings in the simulated hand sweat solution was probed using potentiodynamic polarization test and electrochemical impedance spectroscopy. Fabrication of interstitial coral-like copper nanostructure by self-assembly and spray deposition has been investigated by Chen et al. [2]. It was noted that compared with the superhydrophillic copper surface, the superhydrophobic coating showed better corrosion resistance in 3.5 wt% NaCl solution and artificial sweat. Corrosion reliability of hearing aid (HA) devices is a critical issue due to their exposure to harsh climatic conditions like high

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humidity and temperature, along with the combination of high level of salt contamination from human sweat and environmental pollutants. Statistical analysis of corrosion failure data can provide a better understanding of the failure sequence and cause, which is important as the issue is due to multiple parameter effects on a complex device consisting of many components. Yadav et al. [3] noted that potassium hydroxide (KOH) electrolyte leakage from faulty Zn-air batteries (ZABs) and human sweat were prominent causes of he corrosion failure of hearing aid components. The rate of corrosion failures was found to accelerate during the summer season due to an increase in human perspiration rate and the release of KOH electrolyte from the batteries. Corrosion behaviour of Cu-Zn-Ni-Sn imitation-gold copper alloy in artificial seawater and perspiration has been studied by Yu et al. [4]. The corrosion behavior of many metallic materials used as jewelry in synthetic sweat solution was studied by the electrochemical polarization method by Naser et al. [5]. Results showed that the sample (Cu-Fe alloy) has the majority corrosion potential in negative beside the highest current density as well as the current density reached 366.13 $\mu A.cm^{-2}$. The surface morphology of the surface of corroded specimens was analyzed using scanning electron microscope to show the product of corrosion with damage on the surface of the material. The atmospheric corrosion behaviour of benzotriazole (BTA) treated cu-based coins in synthetic sweat has been investigated by Huang et al. [6]. Electrochemical impedance spectroscopy showed that the protective effect of BTA on copper coins gradually failed in synthetic sweat with the prolongation of immersion time. Wang et al. [7] have studied the bioaccessibility of nickel and cobalt in powders and massive forms of stainless steel, nickel- or cobalt-based alloys, and nickel and cobalt metals in artificial sweat. Electrochemical Characterization of certain Mg-Based alloys in Artificial Perspiration Biofluid for Consumer and Industrial Applications has been done by Heakal and Bakry [8]. ‘Nickel Allergy’ sometimes occurs when nickel-containing articles are in direct and prolonged contact with the skin, leading to corrosion of elemental nickel by sweat, liberating sufficient nickel ions to be absorbed through the skin and initiate an allergenic effect. Whittington and Lo have investigated the ‘Nickel Allergy’ arising from decorative nickel plated and alloyed articles [9]. The steel strings of guitars suffer aggressive corrosion when exposed to human sweat. To mitigate this effect, guitar strings were subjected to cathodic protection by impressed current by Bonastre et al. [10]. To evaluate the corrosion, electrochemical techniques were used to determine the polarization resistance and the instantaneous corrosion rate, as well as the weight loss by gravimetric measurements.

The present work is undertaken to investigate the influence of D-Glucose on the corrosion resistance of SS 18/8 alloy and Gold 22 K alloy in artificial sweat by electrochemical studies such as polarization study and AC impedance spectra.

2. EXPERIMENTAL

Two alloy specimens, namely, SS 18/8 alloy and Gold 22 K alloy were chosen for the present study.

SS 18/8 alloy

18/8 stainless steel is 304 grade stainless steel, which is the most widely used and flexible austenitic form of stainless steel. The numbers 18/8 represent the composition of this steel as 18% chromium and 8% nickel, making it very resistant to corrosion and oxidation. 18/8 stainless steel is also highly durable and can be fabricated with ease. Cleaning the metal is easy and it is available in various appearances and finishes.18/8 stainless steel may also be known as austenite steel or 304 grade steel.

Gold 22 K alloy

In 22K gold, 22 parts of the metal are gold and the rest two comprise metals like silver, zinc, nickel, and other alloys. It is also known as 91.67 percent pure gold. Mixing alloys makes the texture of gold harder and hence jewellery becomes durable.

The metal specimens were encapsulated in Teflon. The metal specimens were polished to a mirror finish and degreased with trichloroethylene. The metal specimens were immersed in artificial sweat (the ISO standard ISO 3160-2), whose composition was: 20g/l NaCl, 17.5 g/l NH_4Cl, 5g/l acetic acid and 15 g/l d,l lactic acid with the pH adjusted to 4.7 by NaOH. In electrochemical studies, the metal specimens were used as working electrodes. Artificial sweat (AS) was used as the electrolyte (10 ml). The temperature was maintained at 37 ± 0.1°C.

Potentiodynamic Polarization Study

In the present exploration, polarization studies were carried out in a CHI Electrochemical work station/ analyzer, model 660A. It was provided with automatic *iR* compensation facility. A three-electrode cell assembly was used. The working electrode was one of the two alloys. A saturated calomel electrode (SCE) was the reference electrode and platinum was the counter electrode. The scan rate (V/S) was 0.01. Hold time at (Efcs) was zero and quit times (s) was two.

From the polarization study, corrosion parameters such as corrosion potential (E_{corr}), corrosion current (I_{corr}), Tafel slopes (anodic = b_a and cathodic = b_c) and linear polarization resistance (LPR) were calculated. LPR monitoring is an effective electrochemical method of measuring corrosion. Monitoring the relationship between electrochemical potential and current generated between electrically charged electrodes in a process stream allows the calculation of corrosion current. If the electrodes are corroding at high rate with the metal ions passing into solution, a small potential applied between the electrodes will produce a high current, and therefore a low polarization resistance. This corresponds to a high corrosion rate.

AC Impedance Spectra

The instrument used for polarization study was used to record AC impedance spectra also. The cell set up was also the same. The real part (Z') and imaginary part (-Z") of the cell impedance were measured in ohms at various frequencies. The details of the experimental conditions are as follows: Initial E (V) = 0; High frequency (Hz) = 1 x 10^5; Low frequency (Hz) = 10; Amplitude (V) = 0.005; Quiet Time (s)=2. Values of the charge transfer resistance (R_t) and the double-layer capacitance (C_{dl}) were calculated.

3. RESULTS AND DISCUSSION

The influence of D-Glucose on corrosion resistance of SS 18/8 alloy immersed in artificial sweat (AS) and the influence of D-Glucose on corrosion resistance of Gold 22 K immersed in artificial sweat (AS) have been investigated by electrochemical methods such as polarization study and AC impedance spectra.

Influence of D-Glucose on corrosion resistance of SS 18/8 alloy immersed in artificial sweat (AS)

Polarisation study and AC impedance spectra have been widely used in corrosion inhibition /protection study to know the corrosion resistance of metals and alloys [11-24].

Analysis of Results of Polarisation study

The Polarization curves of SS 18/8 alloy in AS in the absence and presence of 100 ppm of D-Glucose are shown in Figures 1 and 2 respectively. The corrosion parameters are given in Table 1. In polarization study, when corrosion resistance decreases, LPR decreases and corrosion current increases.

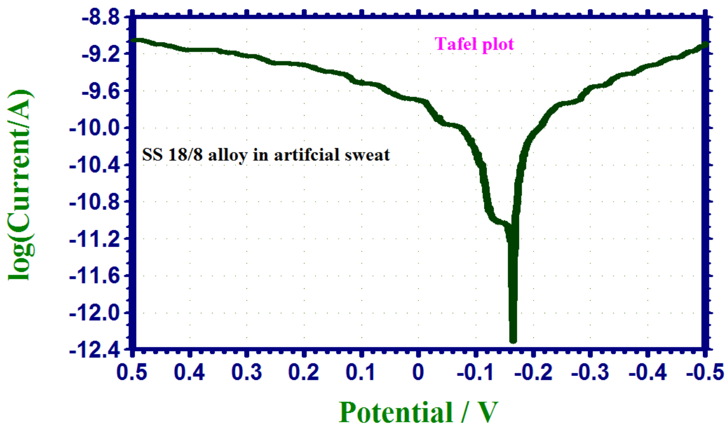

Figure 1. Polarisation curve of SS 18/8 alloy immersed in artificial sweat (AS)

Slika 1. Kriva polarizacije legure SS 18/8 uronjene u veštačkom znoju (AS)

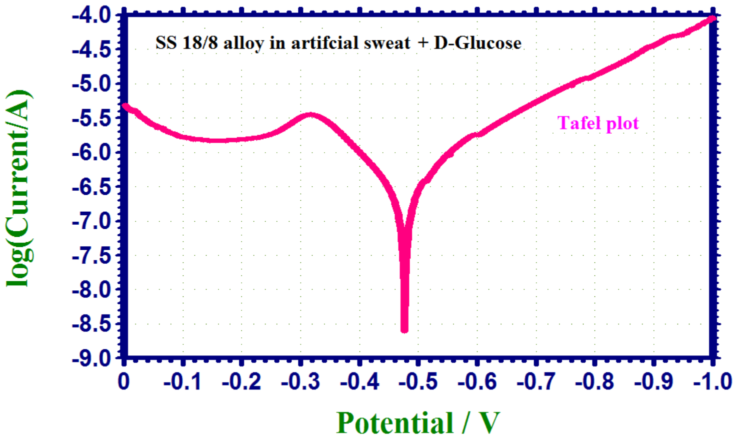

Figure 2. Polarisation curve of SS 18/8 alloy immersed in artificial sweat + D-Glucose

Slika 2. Kriva polarizacije legure SS 18/8 uronjene u veštački znoj + D-glukoza

Table 1. Corrosion parameters of SS 18/8 alloy immersed in various test solutions containing artificial sweat (AS) obtained by Polarization study

Tabela 1. Parametri korozije legure SS 18/8 potopljene u različite test rastvore koji sadrže veštački znoj (AS) dobijeni polarizacionom studijom

System	E_{corr} mV/SCE	b_c mV/decade	b_a mV/decade	LPR Ohm cm^2	I_{corr} A/cm^2
AS	-165	0.4075	0.1719	589308032	8.923×10^{-11}
AS+ D-Glucose 100ppm	-477	144	116	87905	3.168×10^{-7}

It is observed from Table 1, that in the presence of 100 ppm of D-Glucose, the corrosion resistance of SS 18/8 alloy in AS decreases. This is revealed by the fact that, in the presence of 100 ppm of D-Glucose, LPR value of SS 18/8 alloy decreases and corrosion current increases. D-Glucose behaves as cathodic type of inhibitor. This is due to the fact that in the presence of D-Glucose, the corrosion potential is shifted to the cathodic side.

Implication

Corrosion resistance of SS 18/8 alloy in artificial sweat decreases in the presence of 100 ppm of D-Glucose. Hence people having excessive glucose in sweat should avoid wearing ornaments such as wrist watches, rings, and earrings, made of SS 18/8 alloy

Analysis of results of AC impedance spectra

In AC impedance spectra analysis, when corrosion resistance decreases, R_t values phase angle values and impedance values decrease whereas C_{dl} values increase.

The AC impedance spectra of SS 18/8 alloy in AS in the absence and presence of 100 ppm of D-Glucose are shown in Figures 3-6. The Nyquist plots are shown in Figures 3 and 5. The Bode plots are shown in Figures 4 and 6.

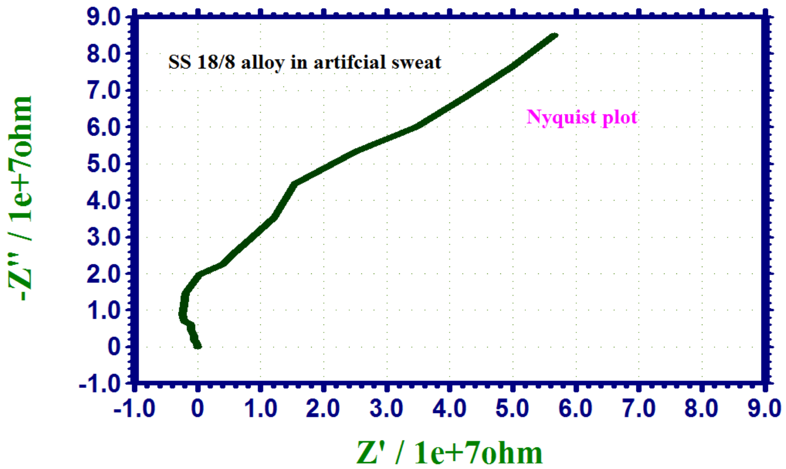

Figure 3. Nyquist plot of SS 18/8 alloy immersed in artificial sweat

Slika 3. Nyquist-ova kriva legure SS 18/8 uronjena u veštački znoj

Table 2. Corrosion parameters of SS 18/8 alloy immersed in various test obtained by AC Impedance spectra

Tabela 2. Parametri korozije legure SS 18/8 potopljene u različitim testovima dobijenim spektrom impedanse naizmenične struje

System	Rt Ohmcm^2	Cdl F/cm^2	Impedance Log(Z/ohm)	Phase angle
AS	57240000	8.9099×10^{-14}	8.023	94
AS + D-Glucose 100ppm	3430	1.4868 x10-9	4.008	54

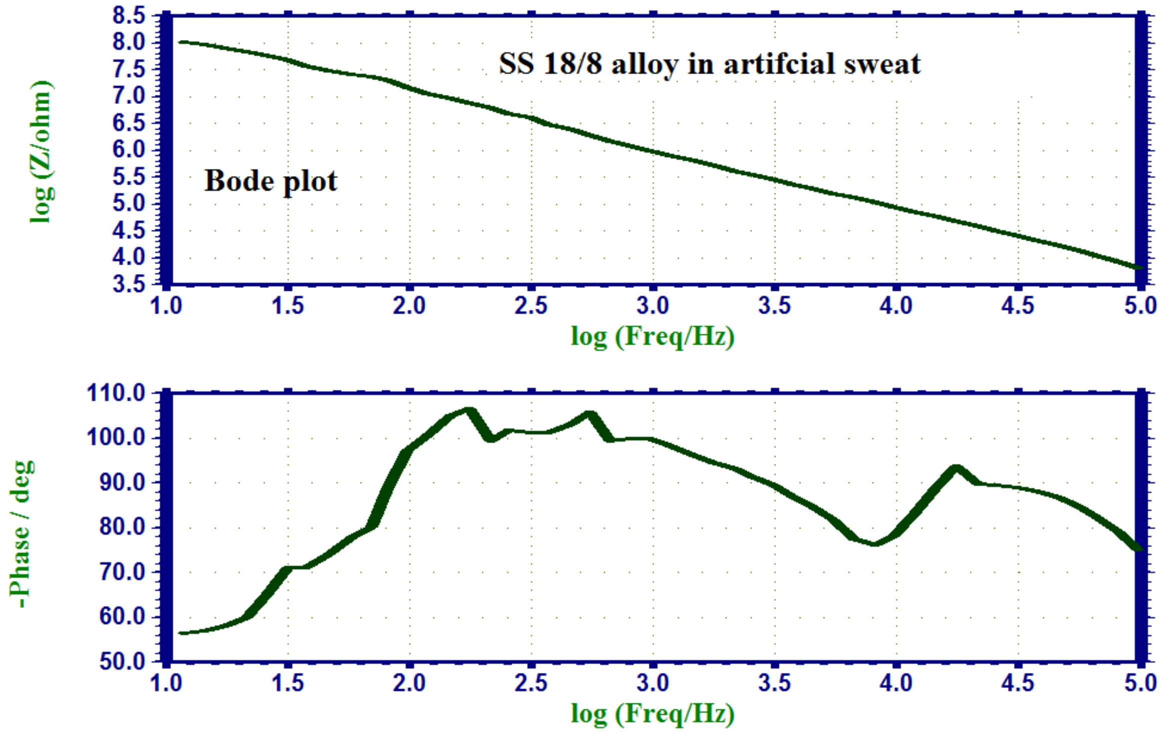

Figure 4. Bode plot of SS 18/8 alloy immersed in artificial sweat

Slika 4. Bode-ova kriva legure SS 18/8 uronjena u veštački znoj

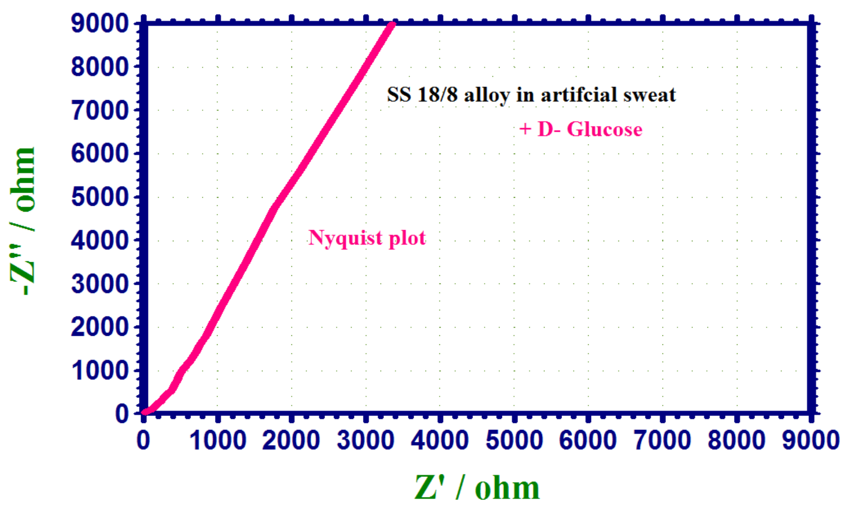

Figure 5. Nyquist plot of SS 18/8 alloy immersed in artificial sweat + D-Glucose

Slika 5. Nyquist-ova kriva legure SS 18/8 uronjena u veštački znoj + D-glukoza

The corrosion parameters such as charge transfer resistance (Rt), impedance value and double-layer capacitance (C_{dl}) values, and phase angle values are given in Table 2. It is observed from Table 2, that in the presence of D-Glucose, the corrosion resistance of SS18/8 alloy in artificial sweat decreases. This is revealed by the fact that in the presence of D-Glucose, R_t value decreases, impedance value decreases, phase angle value decreases and C_{dl} value increases.

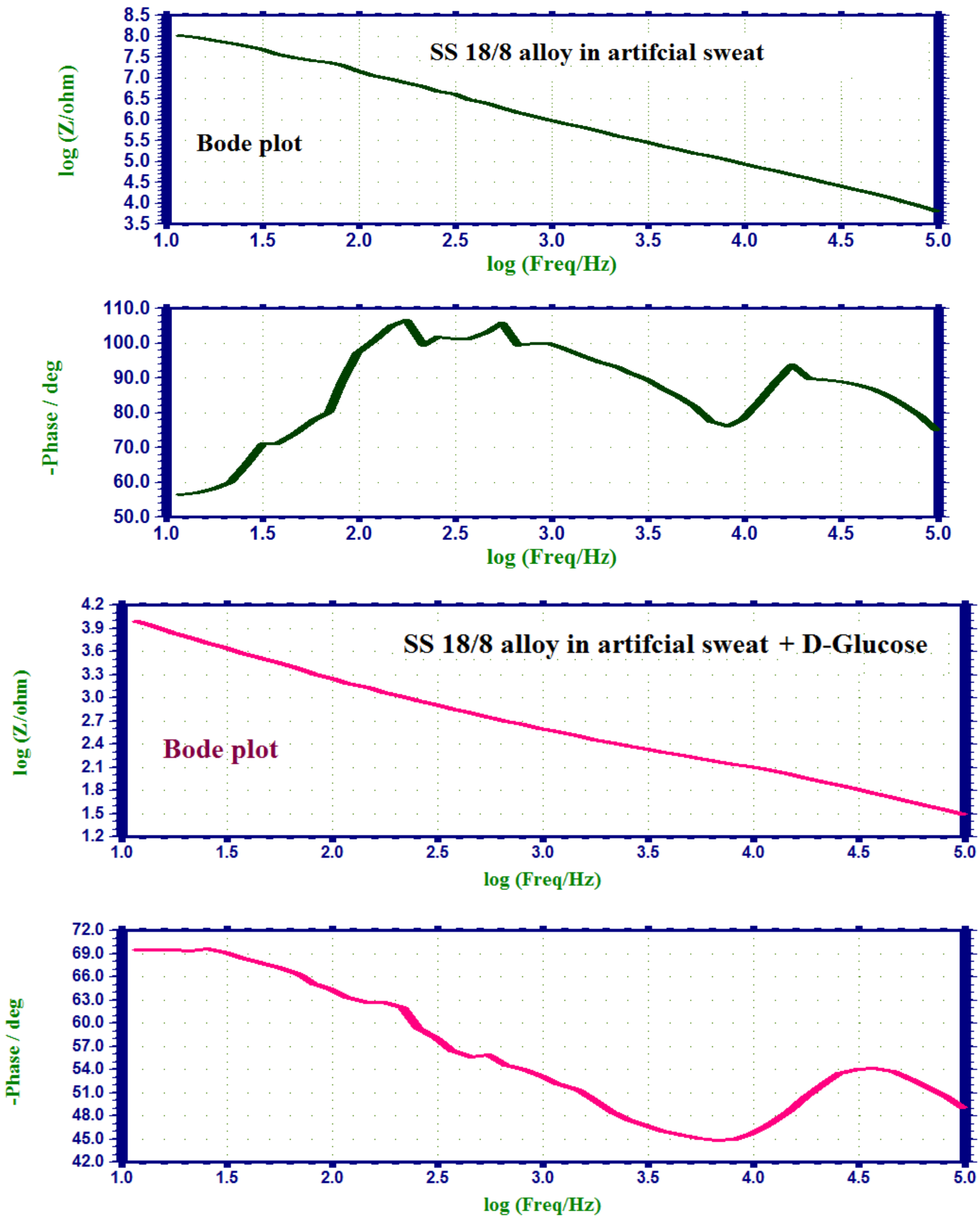

Figure 6. Bode plot of SS 18/8 alloy immersed in artificial sweat + D-Glucose

Slika 6. Bode-ova kriva legure SS 18/8 uronjena u veštački znoj + D-glukoza

Implication

Corrosion resistance of SS18/8 alloy in artificial sweat decreases in the presence of 100 ppm of D-Glucose. Hence people having excess glucose in sweat should avoid wearing ornaments made of SS18/8 alloys, such as wrist watches, rings, bangles, etc.

Influence of D-Glucose on corrosion resistance of Gold 22 K alloy immersed in artificial sweat (AS)

Influence of D-Glucose on corrosion resistance of Gold 22 K alloy immersed in artificial sweat (AS) has been investigated by Polarisation study and AC impedance spectra.

Analysis of Results of Polarisation study

The Polarization curves of Gold 22 K in AS in the absence and presence of 100 ppm of D-Glucose are shown in Figures 7 and 8 respectively. The corrosion parameters are given in Table 3. In polarization study, when corrosion resistance decreases, LPR decreases and corrosion current increases.

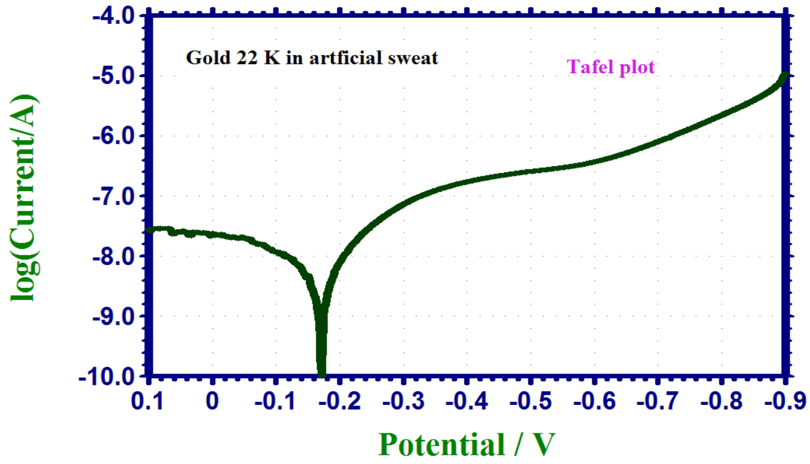

Figure 7. Polarisation curve of Gold 22 K alloy immersed in artificial sweat

Slika 7. Kriva polarizacije legure zlata 22 K uronjena u veštački znoj

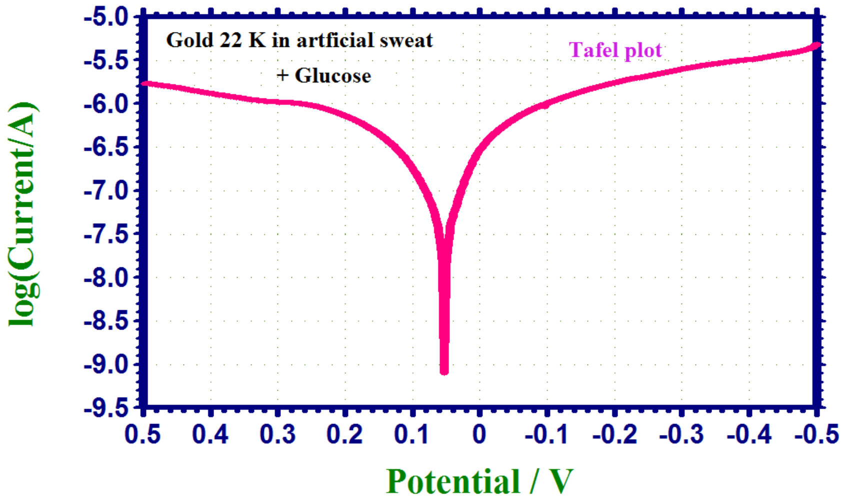

Figure 8. Polarisation curve of Gold 22 K alloy immersed in artificial sweat + D-Glucose

Slika 8. Kriva polarizacije legure zlata 22 K uronjena u veštački znoj + D-glukoza

Table 3. Corrosion parameters of Gold 22 K alloy immersed in various test solutions containing artificial sweat (AS) obtained by Polarisation study

Tabela 3. Parametri korozije legure zlata 22 K potopljene u različite test rastvore koji sadrže veštački znoj (AS) dobijeni polarizacionom studijom

System	E_{corr} mV/SCE	b_c mV/decade	b_a mV/decade	LPR Ohm cm^2	I_{corr} A/cm^2
AS	-172	80	48	4248438	8.038×10^{-9}
AS + D-Glucose 100ppm	53	172	165	236576	1.546×10^{-7}

It is observed from Table 3, that in the presence of 100 ppm of D-Glucose, the corrosion resistance of Gold 22 K alloy in AS decreases. This is revealed by the fact that, in the presence of 100 ppm of D-Glucose, LPR value of Gold 22 K alloy decreases and corrosion current increases.

Implication

Corrosion resistance of Gold 22 K alloy in artificial sweat decreases in the presence of 100 ppm of D-Glucose. Hence people having excessive glucose in sweat should avoid wearing ornaments such as wrist watches, rings, earrings, made of Gold 22 K alloy.

Analysis of results of AC impedance spectra

In AC impedance spectra analysis, when corrosion resistance decreases, R_t values phase angle values and impedance values decrease whereas C_{dl} values increase.

The AC impedance spectra of Gold 22 K alloy in AS in the absence and presence of 100 ppm of D-Glucose are shown in Figures 9-12. The Nyquist plots are shown in Figures 9 and 11. The Bode plots are shown in Figures 10 and 12.

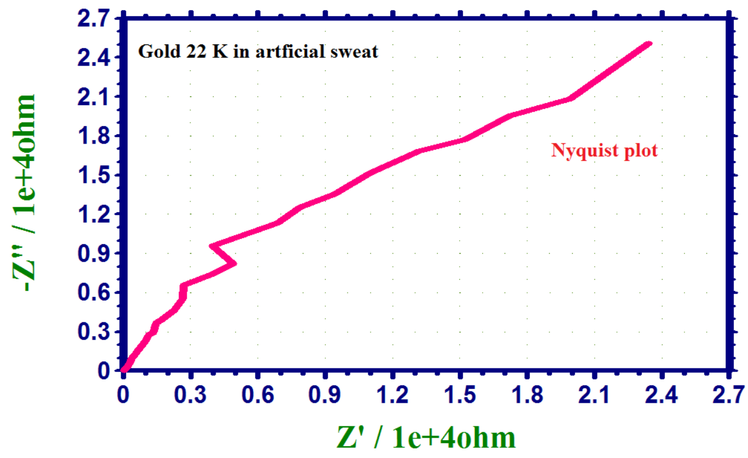

Figure 9. Nyquist plot of Gold 22 K alloy immersed in artificial sweat

Slika 9. Nyquist-ova kriva legure zlata 22K uronjena u veštački znoj

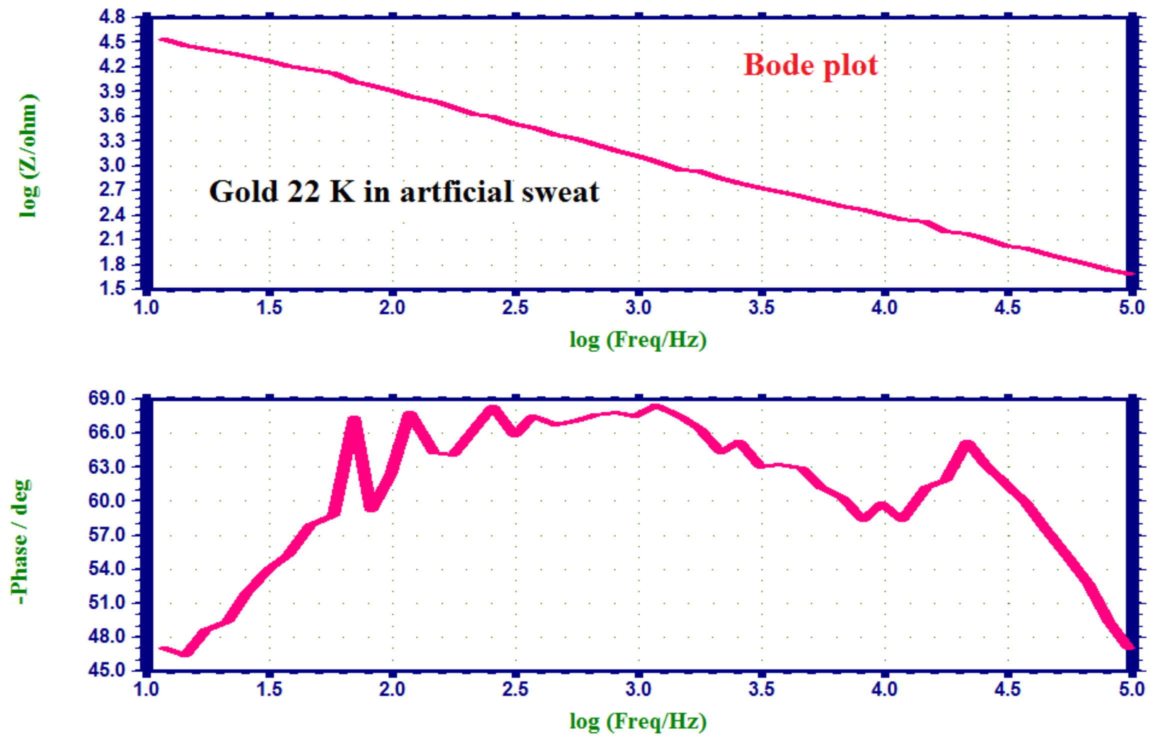

Figure 10. Bode plot of Gold 22 K alloy immersed in artificial sweat

Slika 10. Bode-ova kriva legure zlata 22K uronjena u veštački znoj

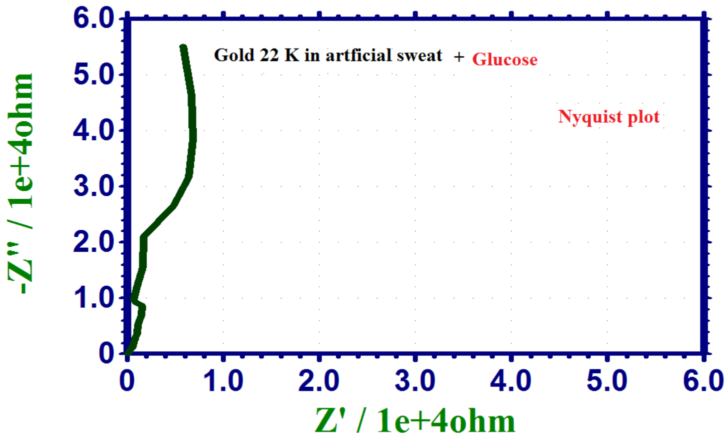

Figure 11. Nyquist plot of Gold 22 K alloy immersed in artificial sweat + D-Glucose

Slika 11. Nyquist-ova kriva legure zlata 22K uronjena u veštački znoj + D-glukoza

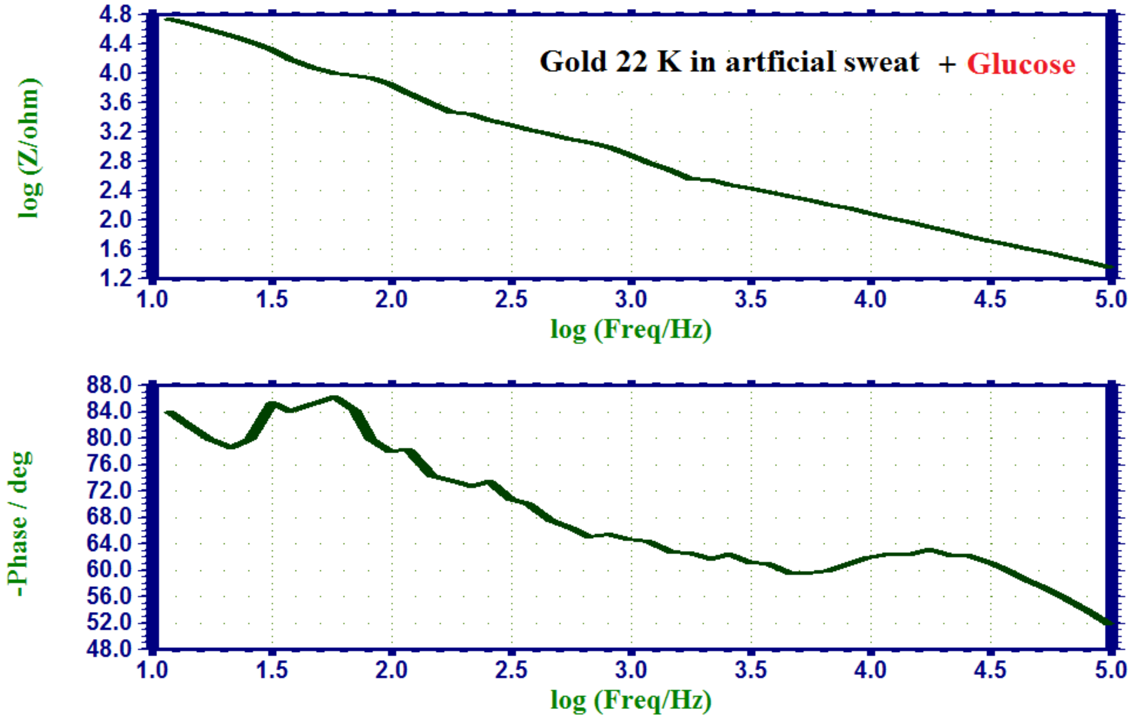

Figure 12. Bode plot of Gold 22 K alloy immersed in artificial sweat + D-Glucose

Slika 12. Bode-ova kriva legure zlata 22K uronjena u veštački znoj + D-glukoza

Table 4. Corrosion Parameters of Gold 22 K alloy immersed in various tests obtained by AC Impedance spectra

Tabela 4. Parametri korozije legure zlata 22 K potopljene u različitim testovima dobijenim spektrom impedanse naizmenične struje

System	R_t Ohmcm^2	C_{dl} F/cm^2	Impedance Log(Z/ohm)	Phase angle°
AS	23680	2.154 x10^{-10}	4.647	66
AS + D-Glucose 100ppm	6336	8.049x10^{-10}	4.567	64

The corrosion parameters such as charge transfer resistance (Rt), impedance value and double-layer capacitance (C_{dl}) values, and phase angle values are given in Table 4.

It is observed from Table 4, that in the presence of D-Glucose, the corrosion resistance of Gold 22 K alloy in artificial sweat decreases. This is revealed by the fact that in the presence of glucose, R_t value decreases, impedance value decreases, phase angle value decreases and C_{dl} value increases.

Implication

The corrosion resistance of Gold 22 K alloy in artificial sweat decreases in the presence of 100 ppm of D-Glucose. Hence people having an excess of ***glucose*** in sweat should avoid wearing ornaments made of SS18/8 alloys, such as wrist watches, rings, bangles, etc.

4. SUMMARY AND CONCLUSIONS

Outcome of the study

Corrosion resistance of SS 18/8 alloy and Gold 22 K alloy in artificial sweat (AS) , in the absence and presence of D-Glucose has been investigated by polarization study and AC impendency spectra. It is inferred that corrosion resistance of SS 18/8 alloy and Gold 22 K alloy in artificial sweat decreases in the presence of D-Glucose. This is revealed by a decrease in LPR value, decrease in Rt value, decrease in impedance value, increase in corrosion current, decrease in phase angle and increase in double-layer capacitance value. Hence people having an excess of D-G***lucose*** in sweat should avoid wearing ornaments made of SS 18/8 alloy and Gold 22 K alloy, such as wrist watches, rings, bangles, etc. The results are summarized in Tables 5 and 6.

Table 5. Summary: Corrosion resistance of SS 18/8 alloy in artificial sweat (AS), in the absence and presence of D-Glucose

Tabela 5. Rezime: Otpornost na koroziju legure SS 18/8 u veštačkom znoju (AS), u odsustvu i prisustvu D-glukoze

Corrosion parameters	Artificial Sweat (AS)	AS+ D-Glucose (100 ppm)	Inference (increases/ decreases)
LPR	589308032	87905	decreases
R_t	57240000	3430	decreases
Impedance	8.023	4.008	decreases
Corrosion current	8.923×10^{-11}	3.168×10^{-7}	increases
Double-layer capacitance	8.9099×10^{-14}	1.4868×10^{-9}	increases
Phase angle°	94	54	decreases
Corrosion potential	-165	-477	Cathodic shift

Table 6. Summary: Corrosion resistance of Gold 22 K alloy in artificial sweat (AS), in the absence and presence of D-Glucose

Tabela 6. Rezime: Otpornost na koroziju legure zlata 22K u veštačkom znoju (AS), u odsustvu i prisustvu D-glukoze

Corrosion parameters	Artificial Sweat (AS)	AS+ D-Glucose (100 ppm)	Inference (increases/ decreases)
LPR	4248438	236576	decreases
R_t	23680	6336	decreases
Impedance	4.647	4.567	decreases
Corrosion current	8.038×10^{-9}	1.546×10^{-7}	increases
Double-layer capacitance	2.154×10^{-10}	8.049×10^{-10}	increases
Phase angle°	66	64	decreases
Corrosion potential	-172	53	Anodic shift

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IZVOD

Otpornost na koroziju legure ss 18/8 i legure zlata 22k u veštačkom znoju u prisustvu d-glukoze

Otpornost na koroziju legure SS 18/8 i legure zlata 22K uronjene u veštački znoj u odsustvu i prisustvu 100ppm D-glukoze je ispitana proučavanjem polarizacije i spektrom impedanse naizmenične struje. Primećeno je da se smanjuje otpornost na koroziju legure SS 18/8 i legure zlata 22K uronjene u veštački znoj u prisustvu 100ppm D-glukoze. Otuda se zaključuje da ljudi koji nose ukrase od ove dve legure moraju da brinu o višku D-glukoze u svom znoju. Kada se legura SS 18/8 uroni u veštački znoj u prisustvu 100ppm D-glukoze, vrednost otpora linearne polarizacije opada sa 589308032Ohmcm^2 na 87905Ohmcm^2; struja korozije raste sa 8,923k10^{-11}A/cm^2 na 4,008k10^{-9}A/cm^2; vrednost otpora prenosa naelektrisanja se povećava sa 4884 Ohmcm^2 na 3,168 k10^{-7} 12210 Ohmcm^2; vrednost impedanse se smanjuje sa 8,023 na 4,008; kapacitivnost dvostrukog sloja se povećava sa 8,9099k10^{-14} F/cm^2 na 1,4868k10^{-9} F/cm^2, a fazni ugao se smanjuje sa 94° na 54°. Kada se legura zlata 22 K potopi u veštački znoj u prisustvu 100 ppm D-glukoze, vrednost otpora linearne polarizacije opada sa 4248438 Ohmcm^2 na 236576 Ohmcm^2; struja korozije raste sa 8,038 k10^{-9}A/cm^2 na 1,546 k10^{-7}A/cm^2; otpor prenosa naelektrisanja se smanjuje sa 23680 Ohmcm^2 na 6336 Ohmcm^2; vrednost impedanse se smanjuje sa 4,647 na 4,567; kapacitivnost dvoslojnog sloja se povećava sa 2,154 k10-$^{-10}$F/cm^2 na 8,049k10^{-10} F/cm^2, a fazni ugao se povećava sa 66° na 64°.

Ključne reči: *Otpornost na koroziju, legura SS 18/8, legura zlata 22K, veštački znoj, D-glukoza, studija polarizacije, spektri impedanse naizmenične struje.*

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