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Research Article

Corrosion Resistance Tests on Various Alloys

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Abstract

The corrosion behavior of various dental alloys such as Ni-Ti alloy, Gold 22 carat, SS18/8, SS316L and Thermoactive alloys were evaluated in Artificial Saliva in the absence and presence of Tea by utilizing electrochemical study such as AC impedance spectra. Corrosion parameters such as Charge Transfer Resistant (R_t), Double Layer Capacitance (C_{dl}) value, impedance value (log (Z/ohm), phase angle were obtained from AC impedance spectra. For Ni-Ti alloy, Gold 22 carat and thermoactive alloy, AC impedance spectra lead to the conclusion that corrosion resistance of Ni-Ti alloy and thermoactive alloy decreases in the order:

AS + Tea > Tea > AS.

The corrosion resistance of Gold 22 carat decreases in the order:

Tea > AS + Tea > AS.

Hence, people implanted with orthodontic wire, made of Ni-Ti alloy, Gold 22 carat and thermoactive alloy can take tea orally without any hesitation. For SS18/8 alloy and SS316L alloy, AC impedance spectra lead to the conclusion that corrosion resistance of SS18/8 alloy and SS316L alloy decreases in the order:

AS > Tea > AS+Tea, AS > AS + Tea > Tea respectively

So, people implanted with orthodontic wire, made of SS18/8 alloy and SS316L alloy should avoid taking tea.

Keywords: *Corrosion Resistance; Orthodontic Wires, Artificial Saliva, Tea, Ni-Ti Alloy, Gold 22 Carat, SS18/8 Alloy, SS316L Alloy and Thermoactive Alloy, AC Impedance Spectra*

Introduction

Dental and orthodontic literature has provided numerals, commentaries on investigations involving physiology and histological responses to orthodontic force. Research and testing of synthetic saliva with physical and chemical properties that duplicate those of normal saliva as nearly as possible have been the most recent objectives of research by Shannon and associates [1]. Austenitic stainless steel (SS) is the alloy of great interest in technological applications wore the material with high corrosion resistance are required. The advantages of SS18/8 compared with other materials are low cost, mechanical properties related to bone material [2]. Orthodontic wires can be made of many materials and alloys. After implantation many food items, many tablets are also orally taken. In the oral environment these orthodontic wire undergo many types of corrosion. Ni-Ti materials are purported to overcome this rapid force decay problem and supply light, continuous force over a long activation range. Ni-Ti alloys possess the unique properties of shape memory and super elasticity [3]. Corrosion resistance of super elastic Ni-Ti alloy in artificial saliva in the absence and presence of a tablet Almox 250 mg has been evaluated by

Rajendran., *et al*. Christy., *et al*. have studied that the influence of corrosion resistance of orthodontic wire in artificial saliva in absence and presence of coffee [4]. Artificial and natural teeth, metallic dental implants, and restorative materials within the mouth interact continually with physiological fluids and the constituents of drinks and food. The choice of the material depends on a number of factors, including: Corrosion behavior, Mechanical properties, Cost, Availability, Biocompatible, Esthetic appearance. Ti alloys are highly corrosive resistant because of the stability of the TiO_2 ode layer, they are not inert to corrosive attack [5-9]. Metallic materials such as Ag, Au, Ni-Ti, Ni-Cr, SS 316L, SS18/8 alloys, etc. are used as implants in regulative oral surgery to the array of teeth. Vieira., *et al.* have studied the tribocorrosion of Ti in artificial saliva (AS) in presence of citric acid and sodium nitrate [10]. Rajendran., *et al.* have studied the corrosion behavior metals in AS in presence of spirulina powder [11]. The corrosion behavior of Aluminium-bronze dental alloy in AS has been studied by polarization test, polarization resistance measurement and weight loss method [12]. Mareci., *et al.* have analysed the corrosion resistance of Ni-Co based alloy in AS [13]. Corrosion behaviors of NiTi orthodontic brackets in AS has been investigated [14]. The influence of eugernol of the corrosion resistance of Ti in AS has been studied [15]. The present work was undertaken to study the Corrosion resistance of Ni-Ti alloy, Gold 22 carat, SS18/8 alloy, SS316L alloy and Thermoactive alloy in artificial saliva in the absence and presence of Tea. By a AC impedance spectra, Charge Transfer Resistant (R_t), Double Layer Capacitance (C_{dl}) value, the impedance value (log (Z/ohm)) were calculated.

Experimental

Orthodontic wires made of Ni-Ti alloy, 22 carat gold, SS18/8 alloy, SS316 alloy and thermoactive alloy are used in the present study. The metal specimens were used as working electrode. They were immersed in Fusayamma Meyer artificial saliva whose composition is:

S. No	Name of the chemicals	Wt/l
1	KCl	0.4g/l
2	NaCl	0.4 g/l
3	Urea	1 g/l
4	$CaCl_2.H_2O$	0.906 g/l
5	$Na_2S.9H_2O$	0.005 g/l
6	$NaH_2PO_4.2H_2O$	0.690 g/l

Table 1*: Composition of Artificial Saliva.*

Result and Discussion

Analysis of AC Impedance Spectra

AC Impedance Spectra has been used to investigate the information of protective film on the metal surface. When a protective film is formed the Charge Transfer Resistant (Rt) increases; Double Layer Capacitance (Cdl) value decreases. The impedance value (log (Z/ohm)) increases [16-20].

Ni – Ti alloy

The AC Impedance spectra of Ni-Ti alloy immersed in various test solutions are shown in figure 1 (Nyquist plot) and figures 2-4 (Bode plots). The corrosion parameters are given in table 2.

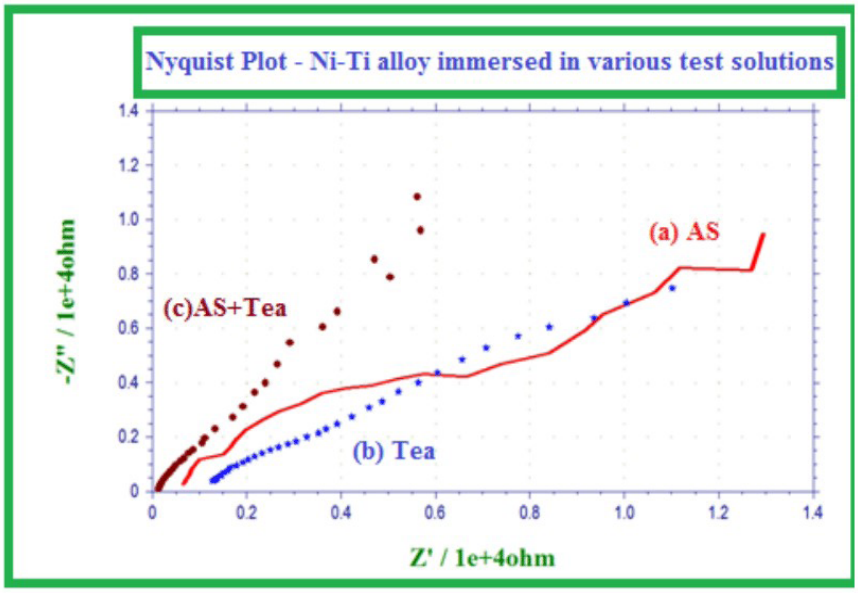

Figure 1: *Impedance spectra (Nyquist plots) of Ni-Ti alloy immersed in various test solutions (a) AS; (b) Tea; (c) AS+Tea.*

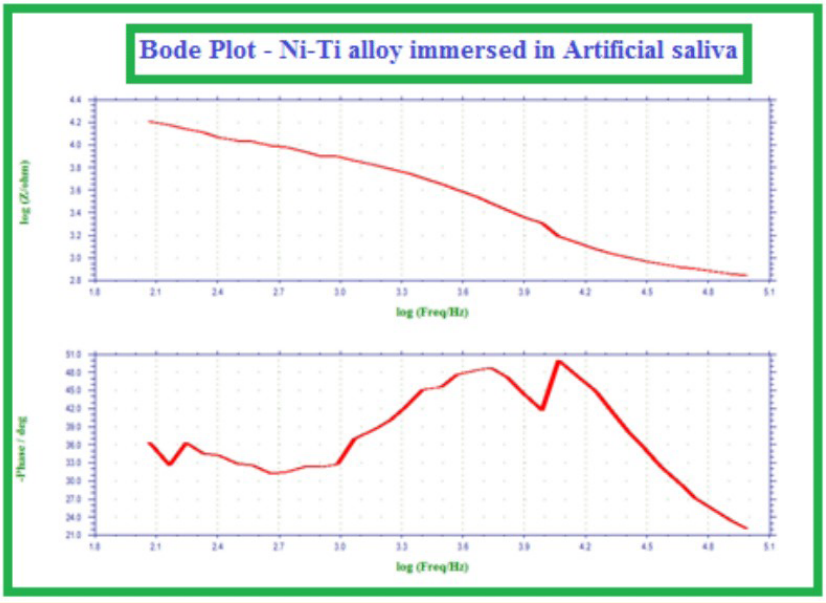

Figure 2: *AC impedance spectra (Bode plot) of Ni-Ti alloy immersed in AS.*

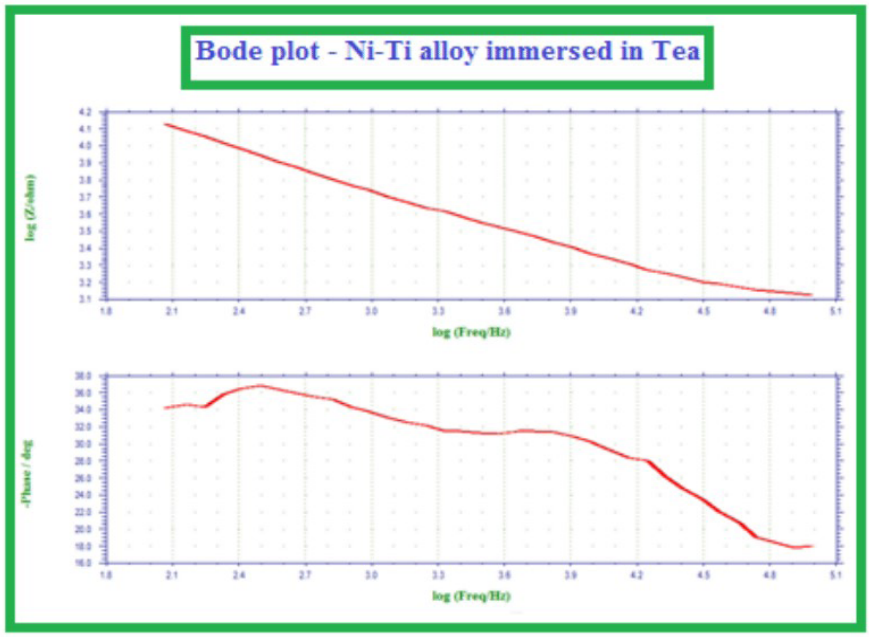

Figure 3: *AC impedance spectra (Bode plot) of Ni-Ti alloy immersed in Tea.*

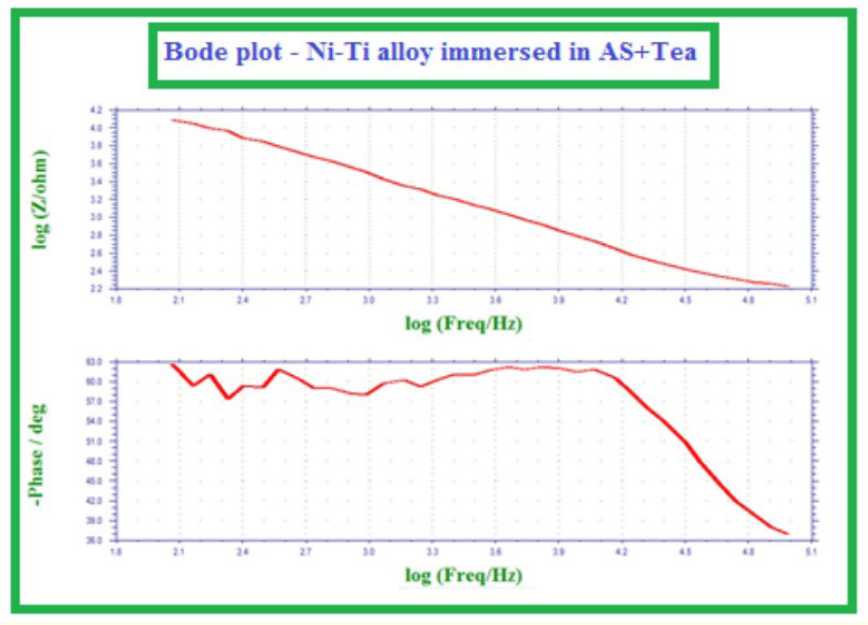

Figure 4: *AC impedance spectra (Bode plot) of Ni-Ti alloy immersed in AS+Tea.*

Metal	System	Nyquist plots		Bode plot
		R_t ohm cm^2	C_{dl} F/cm^2	Impedance Log (Z/ohm)
Ni-Ti alloy	AS	12278	4.1538×10^{-10}	4.203
	Tea	9819	5.194×10^{-10}	4.130
	AS+Tea	56387	2.080×10^{-10}	4.094
Gold 22 carat	AS	14014	3.63911×10^{-10}	4.409
	Tea	51994	9.809×10^{-11}	4.330
	AS+Tea	41618	1.2254×10^{-10}	4.088
SS 18/8 alloy	AS	14789	3.4484×10^{-10}	4.348
	Tea	10330	4.9371×10^{-10}	4.477
	AS+Tea	6961	7.3261×10^{-10}	4.196
SS 316L alloy	AS	12468	4.0905×10^{-10}	4.443
	Tea	2482.8	2.0541×10^{-8}	4.582
	AS+Tea	955473	5.3376×10^{-10}	4.128
Thermoactive alloy	AS	27941	1.8253×10^{-10}	3.871
	Tea	28861	1.767×10^{-10}	4.617
	AS+Tea	28761	1.773×10^{-10}	4.259

Table 2: *Corrosion parameters of alloys immersed in artificial saliva (AS) in the absence and presence of Tea, obtained from AC impedance spectra.*

When Ni-Ti alloy is immersed in AS the Charge Transfer Resistance is (R_t) 12278 ohm cm^2. The Double Layer Capacitance (C_{dl}) value is 4.1538×10^{-10} F/cm^2. The Impedance (log (Z/ohm)) value is 4.203.

When Ni-Ti alloy is immersed in Tea the R_t value decreases from 12278 to 9819 ohm cm^2. The C_{dl} value increases from 4.1538×10^{-10} to 5.194×10^{-10} F/cm^2. The impedance (log (Z/ohm)) value is 4.130. This indicates that corrosion resistant of Ni-Ti alloy further decreases in Tea system than in AS.

When Ni-Ti alloy is immersed in AS + Tea system the Charge Transfer Resistance (R_t) value increases to 56387 ohm cm^2 and Double Layer Capacitance (C_{dl}) value decreases to 2.080×10^{-10} F/cm^2. The Impedance (log (Z/ohm)) value is 4.094. This indicates that the corrosion resistance of Ni-Ti alloy in AS + Tea system further decreases.

Thus AC impedance spectra lead to the conclusion that the corrosion resistance of Ni-Ti alloy immersed in various test solutions decreases in the following order.

AS > Rasam >AS + Rasam

Thus AC impedance spectra leads to the conclusion that people having orthodontic wires made of Ni-Ti alloy should avoid taking rasam orally.

22 Carat Gold

The AC Impedance spectra of 22 carat gold immersed in various test solutions are shown in figure 5 (Nyquist plot) and figures 6-8 (Bode plots). The corrosion parameters are given in table 2.

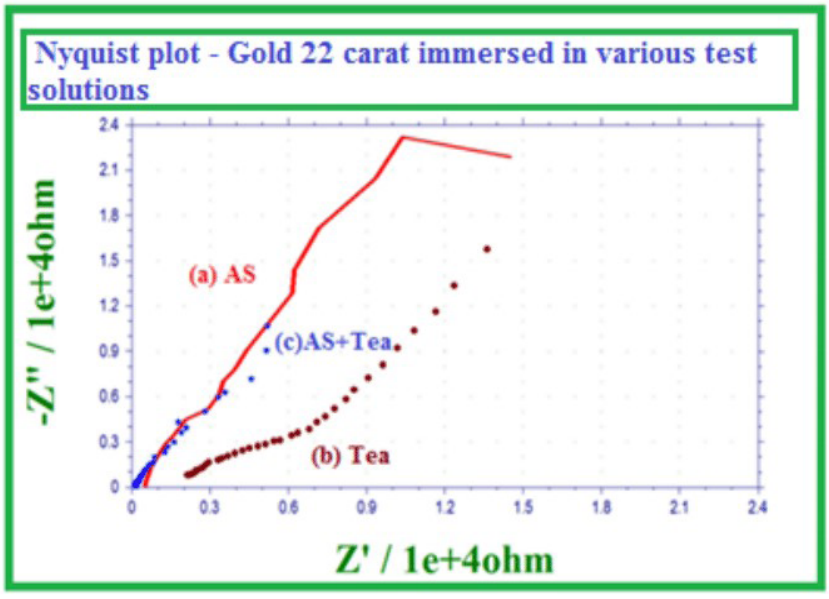

Figure 5: *Impedance spectra (Nyquist plots) of Gold 22 carat immersed in various test solutions (a) AS; (b) Tea; (c) AS+Tea*

Figure 6: *AC impedance spectra (Bode plot) of Gold 22 carat immersed in AS.*

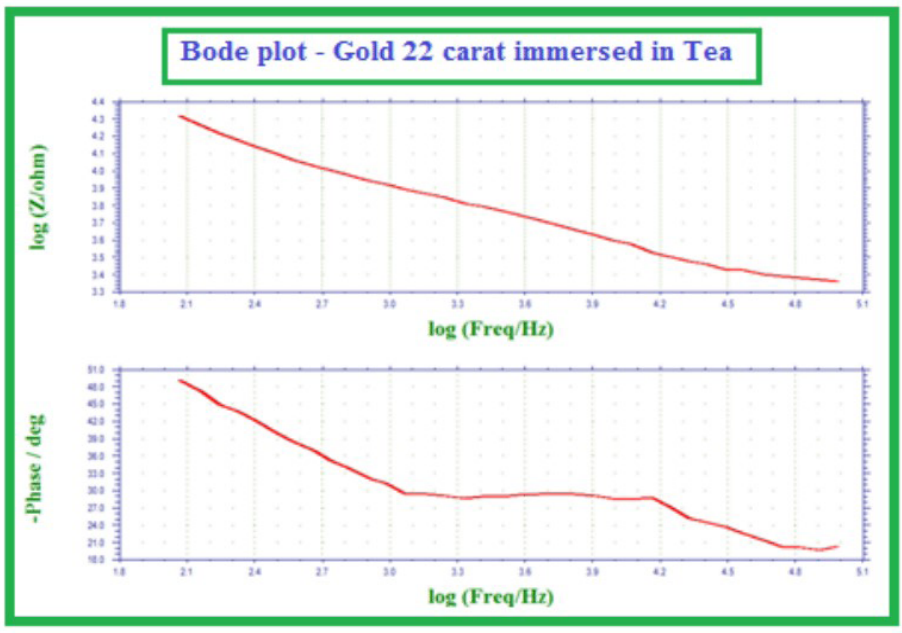

Figure 7: *AC impedance spectra (Bode plot) of Gold 22 carat immersed in Tea.*

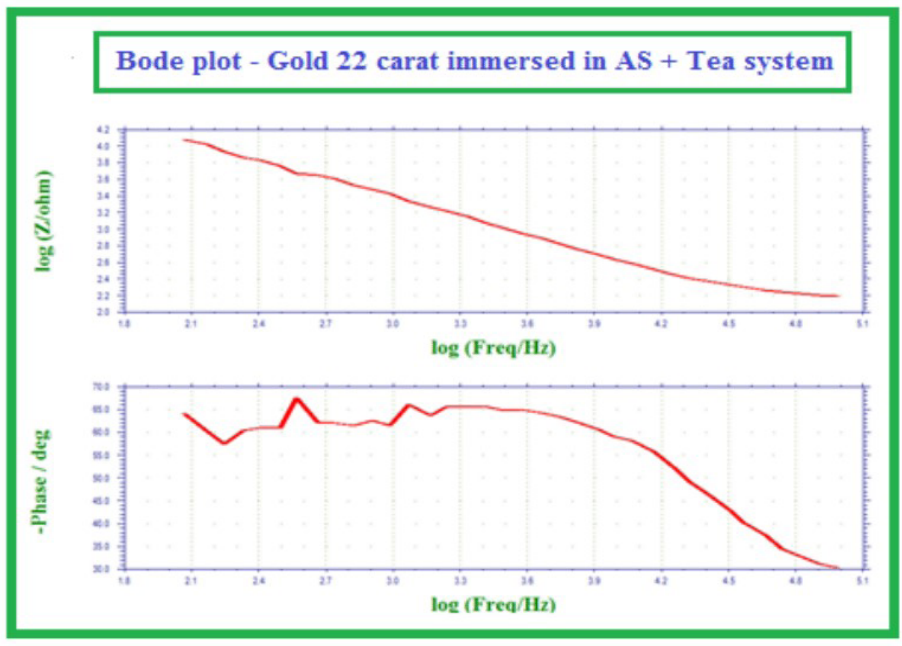

Figure 8: *AC impedance spectra (Bode plot) of Gold 22 carat immersed in AS + Tea.*

When 22 carat gold is immersed in AS the Charge Transfer Resistance is (R_t) 14014 ohm cm^2. The Double Layer Capacitance (C_{dl}) value is 3.63911 x 10^{-10} F/cm^2. The Impedance (log (Z/ohm)) value is 4.409.

When 22 carat gold is immersed in Tea the R_t value increases from 14014 to 51994 ohm cm2. The Cdl value decreases from 3.63911 x 10^{-10} to 9.809 x 10^{-11} F/cm^2. The impedance value increases from 4.409 to 4.330. This indicates that 22 carat gold is more corrosion resistant than in AS.

When 22 carat gold is immersed in AS + Tea system the Charge Transfer Resistance (R_t) value is 41618 ohm cm^2 and Double Layer Capacitance (C_{dl}) value is 1.2254 x 10^{-10} F/cm^2. The Impedance (log (Z/ohm)) value is 4.088. This reveals that the corrosion resistance of 22 carat gold in AS + Tea system increases than AS system.

Thus AC impedance spectra leads to the conclusion that the corrosion resistance of 22 carat gold immersed in various test solutions decreases in the following order.

Tea >AS + Tea > AS

Thus AC impedance spectra leads to the conclusion that people having orthodontic wires made of 22 carat gold need not hesitate to take Tea orally.

SS 18/8 alloy

The AC Impedance spectra of SS 18/8 alloy immersed in various test solutions are shown in figure 9 (Nyquist plot) and figures 10-12 (Bode plots). The corrosion parameters are given in table 2.

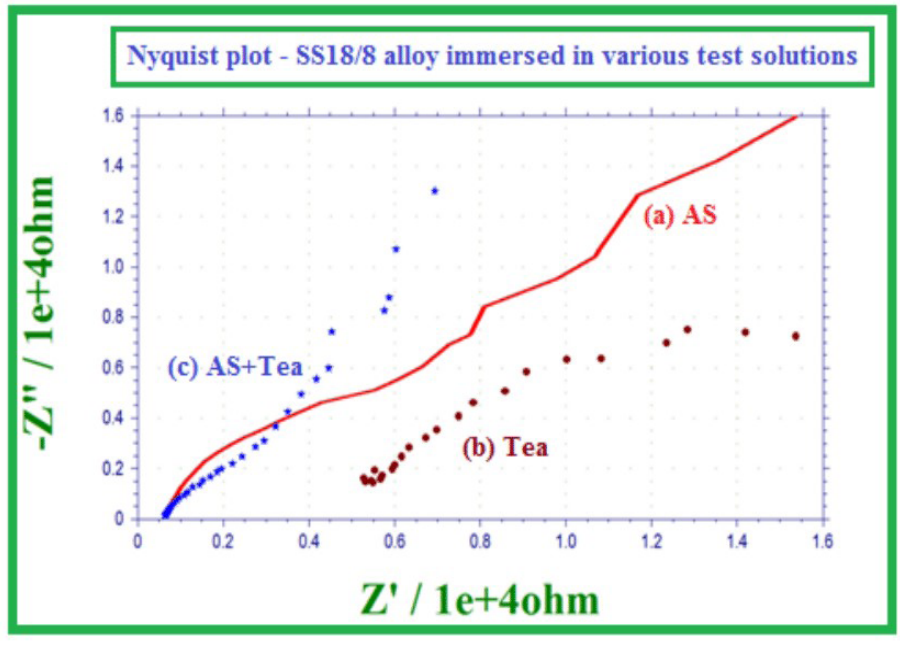

Figure 9: *Impedance spectra (Nyquist plots) of SS 18/8 alloy immersed in various test solutions (a) AS; (b) Tea; (C) AS+Tea.*

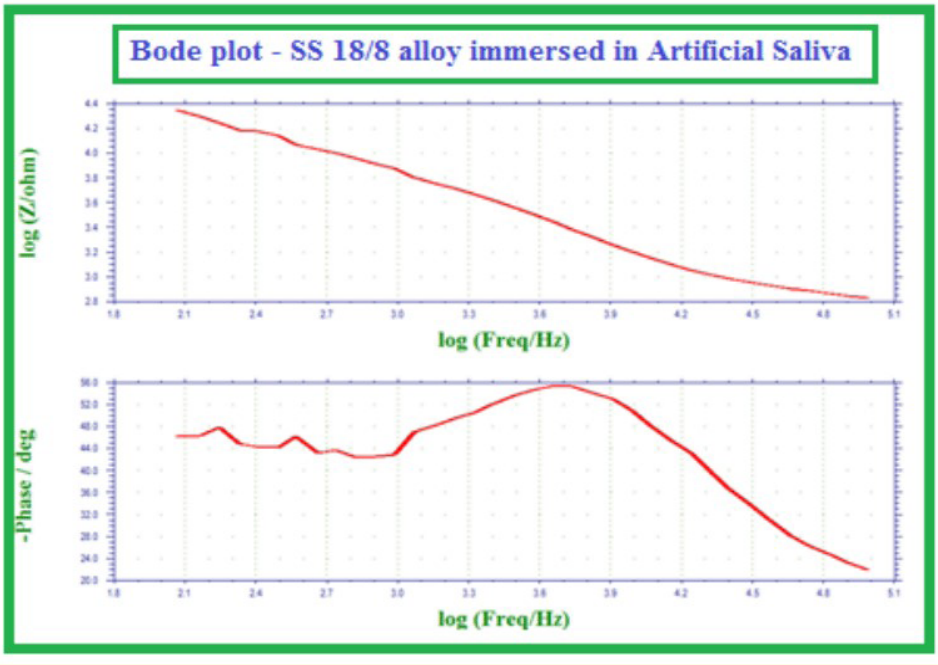

Figure 10: *AC impedance spectra (Bode plot) of SS 18/8 alloy immersed in AS.*

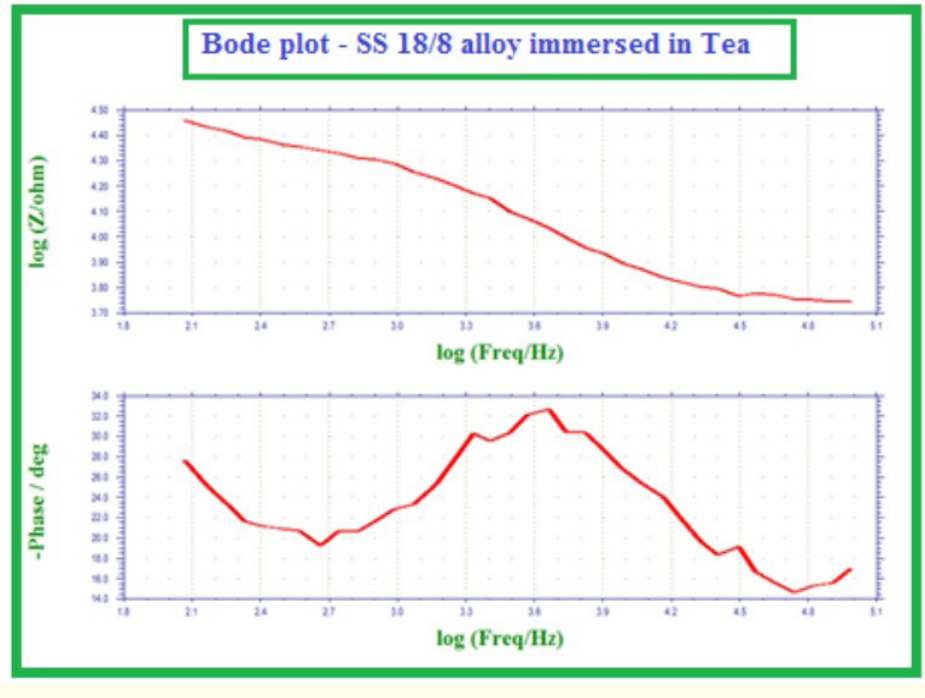

Figure 11: *AC impedance spectra (Bode plot) of SS 18/8 alloy immersed in Tea.*

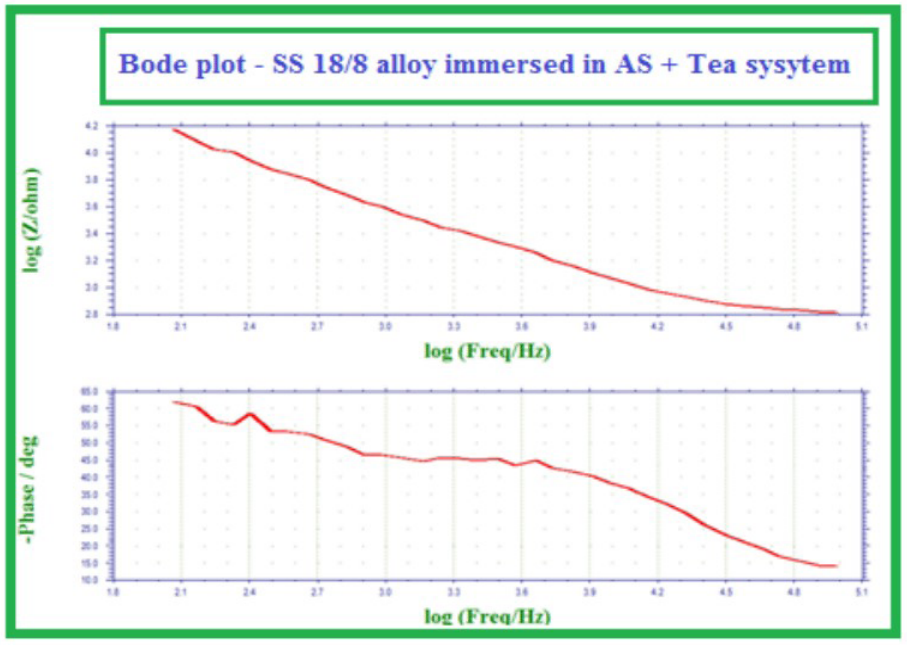

Figure 12: *AC impedance spectra (Bode plot) of SS 18/8 alloy immersed in AS + Tea.*

When SS 18/8 alloy is immersed in AS the Charge Transfer Resistance is (R_t) 14789 ohm cm^2. The Double Layer Capacitance (C_{dl}) value is 3.4484 x 10^{-10} F/cm^2. The Impedance (log (Z/ohm)) value is 4.348.

When SS 18/8 alloy is immersed in Tea the R_t value decreases from 14789.3 to 10330 ohm cm^2. The C_{dl} value increases from 3.4484 x 10^{-10} to 4.9371 x 10^{-10} F/cm^2. The impedance value increases from 4.348 to 4.477. This indicates that SS 18/8 alloy is more corrosion resistant than in AS.

When SS 18/8 alloy is immersed in AS + Tea system the Charge Transfer Resistance (R_t) value decreases to 6961 ohm cm^2 and Double Layer Capacitance (C_{dl}) value increases to 7.3261 x 10^{-10} F/cm^2. The Impedance (log (Z/ohm)) value is 4. 196.This reveals that the corrosion resistance of SS 18/8 alloy in AS + Tea system further decreases.

Thus AC impedance spectra leads to the conclusion that the corrosion resistance of SS 18/8 alloy immersed in various test solutions decreases in the following order.

AS > Tea > AS + Tea

Thus AC impedance spectra leads to the conclusion that people having orthodontic wires made of SS 18/8 alloy should avoid to take Tea orally.

SS316L alloy

The AC Impedance spectra of SS 18/8 alloy immersed in various test solutions are shown in figure 13 (Nyquist plot) and figures 14-16 (Bode plots).

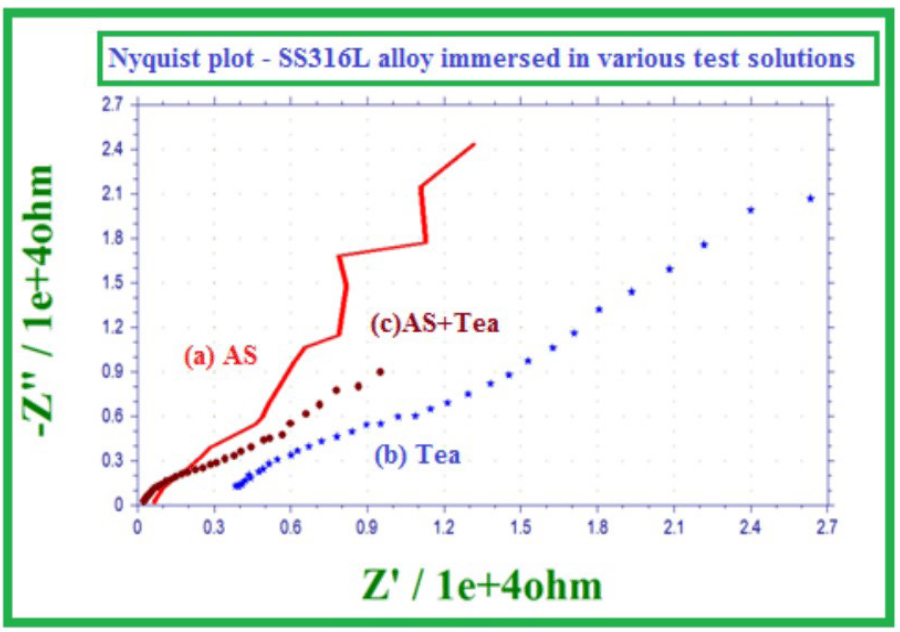

Figure 13: *Impedance spectra (Nyquist plots) of SS 316L alloy immersed in various test solutions (a) AS; (b) Tea; (C) AS+Tea.*

Figure 14: *AC impedance spectra (Bode plot) of SS 316L alloy immersed in AS.*

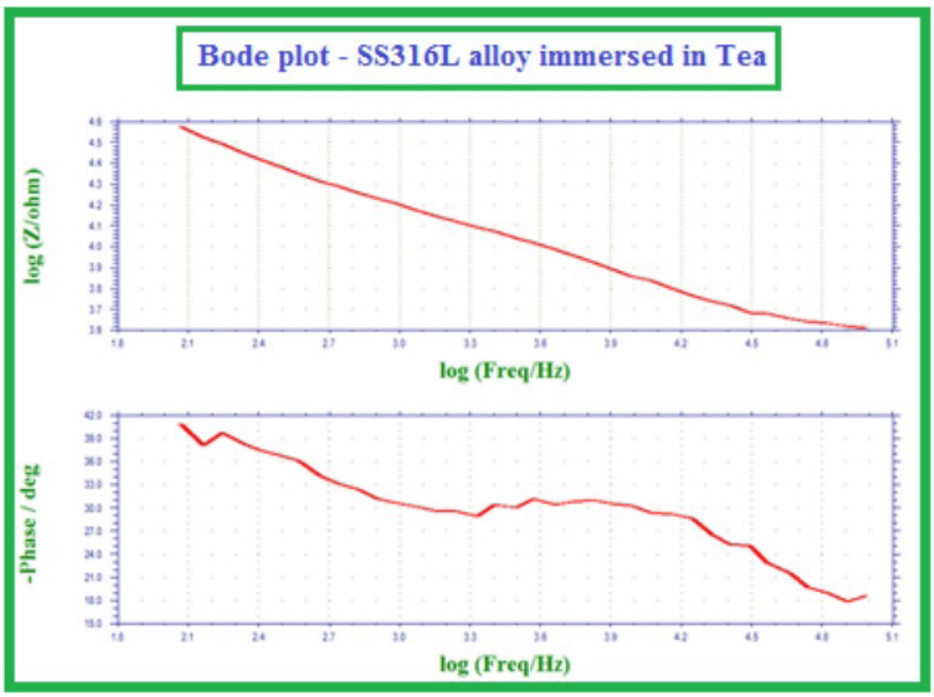

Figure 15: *AC impedance spectra (Bode plot) of SS 316L alloy immersed in Tea.*

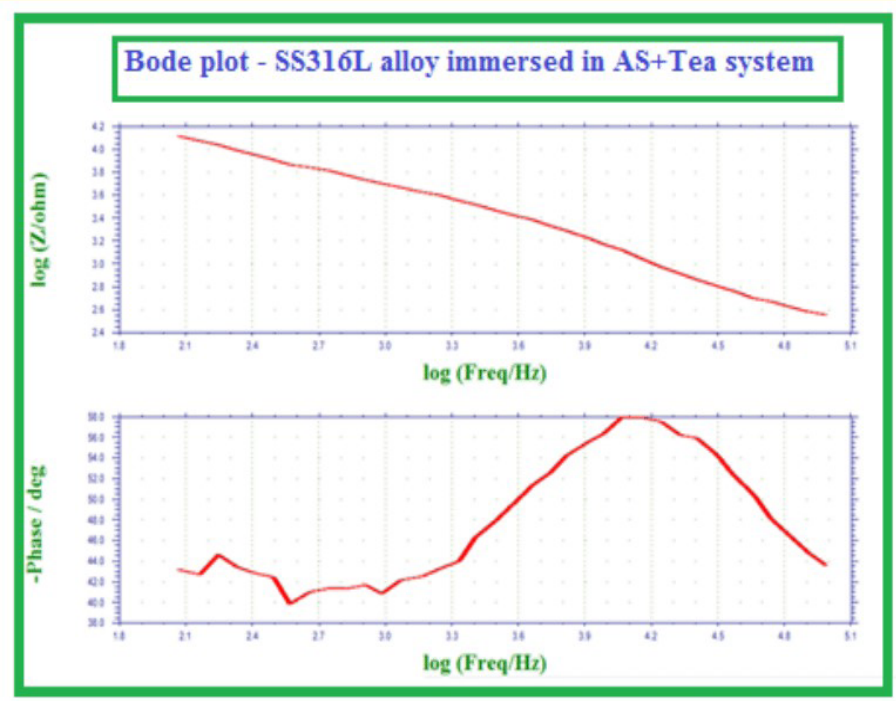

Figure 16: *AC impedance spectra (Bode plot) of SS 316L alloy immersed in AS + Tea.*

When SS 18/8 alloy is immersed in AS the Charge Transfer Resistance is (R_t) 12468 ohm cm^2. The Double Layer Capacitance (C_{dl}) value is 4.0905 x 10^{-10} F/cm^2. The Impedance (log (Z/ohm)) value is 4.443.

When SS 18/8 alloy is immersed in Tea the R_t value decreases from 12468 to 2482.8 ohm cm^2. The C_{dl} value increases from 4.0905 x 10^{-10} to 2.0541 x 10^{-8} F/cm^2. The impedance value increases from to 4.582. This indicates that SS 18/8 alloy is less corrosion resistant than in AS.

When SS 18/8 alloy is immersed in AS + Tea system the Charge Transfer Resistance (R_t) value decreases to 9554.73 ohm cm^2 and Double Layer Capacitance (C_{dl}) value increases to 5.3376 x 10^{-10} F/cm^2. The Impedance (log (Z/ohm)) value is 4.128. This suggest that the corrosion resistance of SS 18/8 alloy in AS + Tea system further increases than Tea system and decreases than AS system.

Thus AC impedance spectra leads to the conclusion that the corrosion resistance of SS 18/8 alloy immersed in various test solutions decreases in the following order.

AS > AS + Tea > Tea

Thus AC impedance spectra leads to the conclusion that people having orthodontic wires made of SS 18/8 alloy should avoid to take Tea orally.

Thermoactive alloy

The AC Impedance spectra of thermoactive alloy immersed in various test solutions are shown in figure 17 (Nyquist plot) and figures 18-20 (Bode plots). The corrosion parameters are given in table 2.

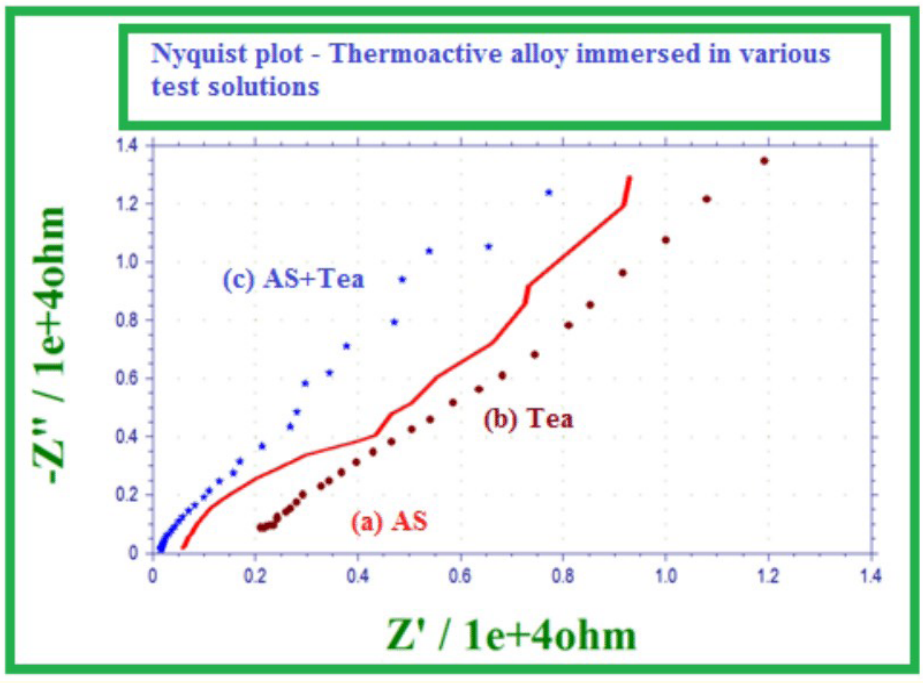

Figure 17: *Impedance spectra (Nyquist plots) of Thermoactive alloy immersed in various test solutions (a) AS; (b) Tea; (C) AS+Tea.*

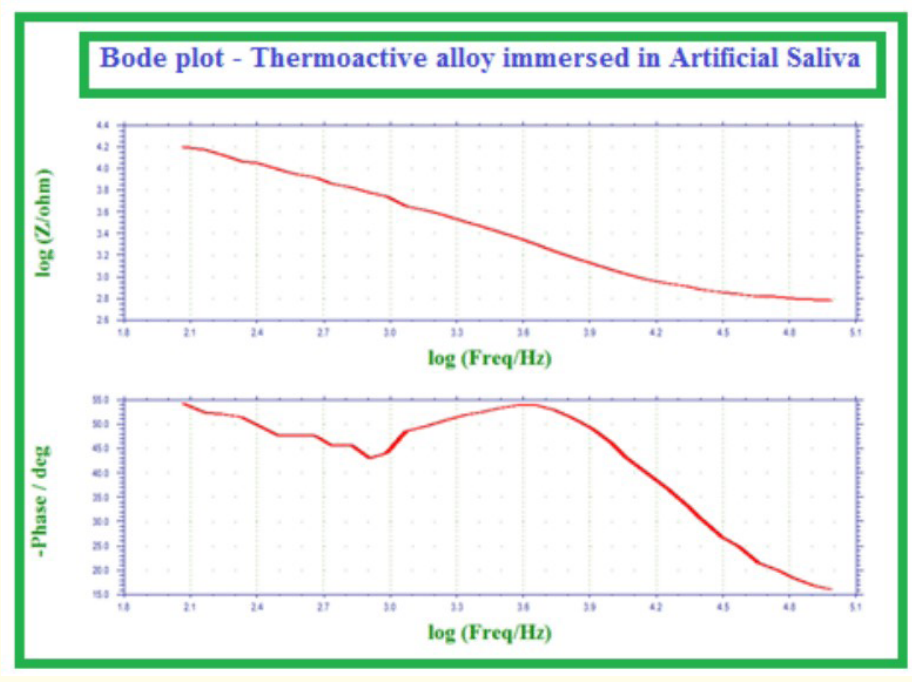

Figure 18: *AC impedance spectra (Bode plot) of SS 316L alloy immersed in AS.*

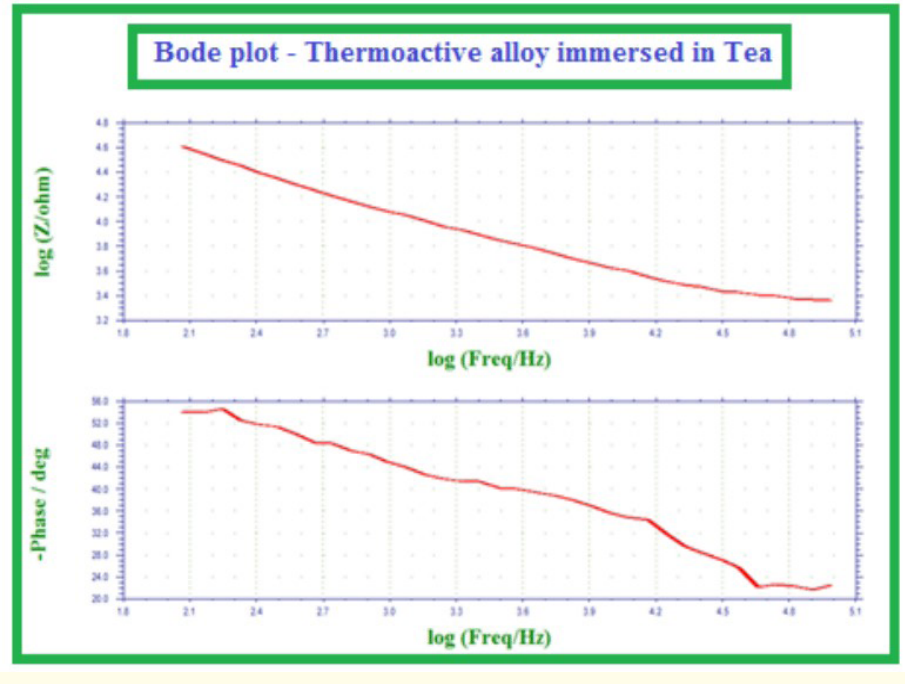

Figure 19: *AC impedance spectra (Bode plot) of Thermoactive alloy immersed in Tea.*

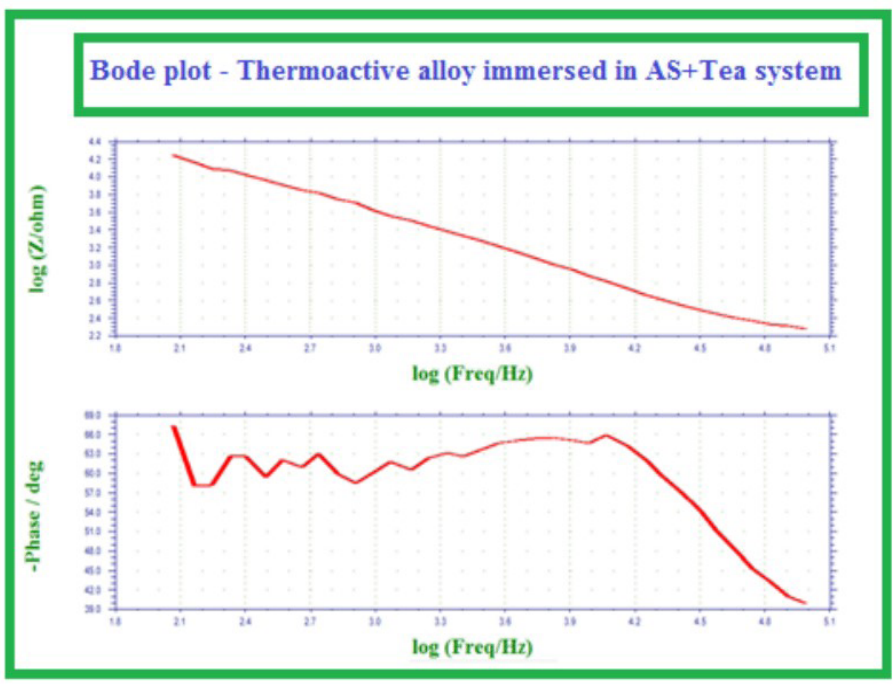

Figure 20: *AC impedance spectra (Bode plot) of Thermoactive alloy immersed in AS + Tea.*

When thermoactive alloy is immersed in AS the Charge Transfer Resistance is (R_t) 27941 ohm cm^2. The Double Layer Capacitance (C_{dl}) value is 1.8253 x 10^{-10} F/cm^2. The Impedance (log (Z/ohm)) value is 3.871.

When thermoactive alloy is immersed in Tea the R_t value increases from 27941 to 28861 ohm cm^2. The C_{dl} value decreases to 1.767 x 10^{-10} F/cm^2. The impedance (log (Z/ohm)) value is 4.617. This indicates that corrosion resistant of thermoactive alloy increases in Tea system than in AS.

When thermoactive alloy is immersed in AS + Tea system the Charge Transfer Resistance (R_t) value decreases to 28761 ohm cm^2 and Double Layer Capacitance (C_{dl}) value increases to 1.773 x 10^{-10} F/cm^2. The Impedance (log (Z/ohm)) value is 4.259. This indicates that the corrosion resistance of thermoactive alloy in AS + Tea system further decreases.

Thus AC impedance spectra leads to the conclusion that the corrosion resistance of thermoactive alloy immersed in various test solutions decreases in the following order.

Tea > AS +Tea >AS

Thus AC impedance spectra leads to the conclusion that people having orthodontic wires made of thermoactive alloy need not hesitate to take Tea orally.

Conclusion

- For Ni-Ti alloy, Gold 22 carat and thermoactive alloy, AC impedance spectra lead to the conclusion that corrosion resistance of Ni-Ti alloy and thermoactive alloy decreases in the order:

  AS + Tea > Tea > AS

- The corrosion resistance of Gold 22 carat decreases in the order:

  Tea > AS + Tea > AS

- Hence, people implanted with orthodontic wire, made of Ni-Ti alloy, Gold 22 carat and thermoactive alloy can take tea orally without any hesitation.
- For SS18/8 alloy and SS316L alloy, AC impedance spectra lead to the conclusion that corrosion resistance of SS18/8 alloy and SS316L alloy decreases in the order:

  AS > Tea > AS+Tea, AS > AS + Tea >Tea respectively.

- So, people implanted with orthodontic wire, made of SS18/8 alloy and SS316L alloy should avoid taking tea.

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