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# Influence of dilution and addition of soda water on the corrosion resistance of orthodontic wires immersed in artificial saliva in presence of Copper Barrel, a hard drink

## ABSTRACT

*Copper barrel brandy can be taken orally with dilution of bisleri water or soda water and without dilution. People clipped with orthodontic wires may take copper barrel brandy orally, with dilution of without dilution. How far theorthodontic wires will be affected by these items? To find an answer the present research work is undertaken.Corrosion resistance of orthodontic wires made of Ni-Ti alloy and Ni-Cr alloy in artificial saliva in the absence and presence of copper barrel, water and soda water has been evaluated by AC impedance spectra. It is generally observed that Ni-Ti alloy is more corrosion resistant than Ni-Cr alloy in artificial saliva in the presence of copper barrel, water and soda water. When orthodontic wire made of Ni-Ti is immersed in artificial saliva, the charge transfer resistance ($R_t$) value is 31945Ohmcm$^2$. When it is immersed in copper barrel + artificial saliva (AS) system, $R_t$value increase to 80000Ohmcm$^2$. When it is immersed in soda water + artificial saliva (AS) system, $R_t$value increase to 76450Ohmcm$^2$. When it is immersed in water + artificial saliva (AS) system, $R_t$value increase to 82620Ohmcm$^2$. On the other hand, when orthodontic wire made of Ni-Cr is immersed in artificial saliva, the charge transfer resistance ($R_t$) value is 80930Ohmcm$^2$. When it is immersed in copper barrel + artificial saliva (AS) system, $R_t$value decrease to 11104Ohmcm$^2$. When it is immersed in soda water + artificial saliva (AS) system, $R_t$value decrease to 10437Ohmcm$^2$. It implies that the people who have been clipped with orthodontic wire made of Ni-Ti alloy can take copper barrel in any form, namely, with dilution or without dilution. The people who have been clipped with orthodontic wire made of Ni-Cr alloy should avoid taking copper barrel in any form, namely, with dilution or without dilution.*

***Keywords:****orthodontic wires, corrosion resistance, soda water, artificial saliva, a hard drink, Ni-alloys*

## 1. 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.

Feng et al. have studied the Corrosion Resistance of SLM Denture Scaffold in Simulated Oral Environment [1]. Corrosion of Dental Alloys Used for Mini Implants in Simulated Oral Environment has been investigated by Curkovic et al. [2]. "A Study of the Tribocorrosion occurring at the implant and implant alloy Interface: Dental implant materials" has been undertaken by Mehkri

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et al.[3].Electrochemical corrosion behavior of LDX 2101® duplex stainless steel in a fluoride-containing environment has been studied by Rosalbino et al. [4]. Mindivan et al. have studied the Microstructure and tribocorrosion properties of pulsed plasma nitrided cast CoCr alloy for dental implant applications [5]. Fretting and fretting corrosion processes of Ti6Al4V implant alloy in simulated oral cavity environment have been investigated by Klekotka et al.[6]. The effect of Cu-doping on the corrosion behavior of NiTi alloy arch wires under simulated clinical conditions has been reported by Wang et al.[7]. In the present study, corrosion resistance of orthodontic wires made of Ni-Ti alloy and Ni-Cr alloy in artificial saliva in the absence and presence of copper barrel, water and soda water has been evaluated by AC impedance spectra.

## 2. EXPERIMENTAL

*Ni-Ti alloy*

Ni-Ti alloy (also known as Nitinol) is an alloy with a near-equiatomic composition (i.e., 49%–51%) of nickel and titanium. Ni-Ti belongs to the class of shape memory alloys that can be deformed at a low temperature and are able to recover their original, permanent shape when exposed to a high temperature.The nickel-titanium alloy Nitinol has been used in the manufacture of endodontic instruments in recent years. Nitinol alloys have greater strength and a lower modulus of elasticity compared with stainless steel alloys[8].

*Nickel–chromium (Ni–Cr) alloy*

Nickel–chromium (Ni–Cr) alloys have been used for dental prostheses because of their low prices andexcellent properties in veneered restorations. While most Ni-Cr restorations perform well clinically,corrosion *products and components of these alloys are known* to have the potential to causehypersensitivity and other tissue reactions. The nickel content of nickel-chromium alloys can be as high as 73.5%[9].

*Preparation of artificial saliva*

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

*Copper Barrel brandy*

It is an Indian brandy, made from molasses/Grain spirit, in Kals Distilleries Pvt. Ltd., Kallakottai village, Pudukottai District, Tamilnadu. It cntains demineralised water, neutral spirit, permitted natural colour INS 150a ( A dark brown food color produced by heat treatment of sucrose. It is a food additive approved by the European Union and is denoted by INS150a under International Numbering System.) and permitted flavours.

*AC impedance spectra*

A CHI 660 A workstation model was used in the electrochemical studies. AC impedance spectra were recorded using a three electrode cell assembly.Ni-Ti alloy / Ni-Cr alloy was used as working electrode, platinum as counter electrode and saturated calomel electrode (SCE) as reference electrode.

## 3. RESULTS AND DISCUSSION

Corrosion resistance of two orthodontic wires,namely, Ni-Ti alloy and Ni-Cr alloy in various systems was evaluated by AC impedance spectra (EIS ). The results are discussed in this section.

*Ni-Ti alloy system*

Electrochemical studies such as AC impedance spectra have been used to investigate the corrosion resistance of metals and alloys in various environments [10-20].

Corrosion resistance of orthodontic wire made of Ni-Ti alloy in artificial saliva in the absence and presence of Copper barrel , water and soda water has been evaluated by AC impedance spectra. The results are shown in Table1, SchemeA and Figures 1 to 9. When corrosion resistance increases $R_t$ (Charge transfer resistance) value increases, impedance increases and double layer capacitance ($C_{dl}$) decreases.

*One component system*

When Ni-Ti alloy is immersed in one component system, namely,copper barrel or water or soda water the corrosion resistances are as follows (Table1):

Copper barrel > water>soda water> artificial saliva

*Implication*

Copper barrel alone or water alone or soda water alone can be taken orally, without any hesitation by the people who have been clipped with orthodontic wire made of Ni-Ti alloy.

*Three component system*

When Ni-Ti alloy is immersed in three component system, namely,copper barrel , water and soda water the corrosion resistances are as follows (Table1):

$$CB + Soda + AS > CB + W + AS > AS$$

*Implication*

When copper barrel is mixed with soda water, corrosion resistance of Ni-Ti alloy in artificial saliva, is found to be more than that of the system consisting of copper barrel and water in the presence of artificial saliva. Mixing copper barrel with soda water is better than mixing with water, for those people having clipped with orthodontic wire made of Ni-Ti alloy.

*Two component system*

When copper barrel alone or soda water alone or water alone, is orally intaken, corrosion resistance of Ni-Ti alloy in artificial saliva is as follows (Table 1):

Water alone > copper barrel alone > soda water alone > artificial saliva

*Implication*

Copper barrel alone or water alone or soda water alone can be taken orally, without any hesitation by the people who have been clipped with orthodontic wire made of Ni-Ti alloy.

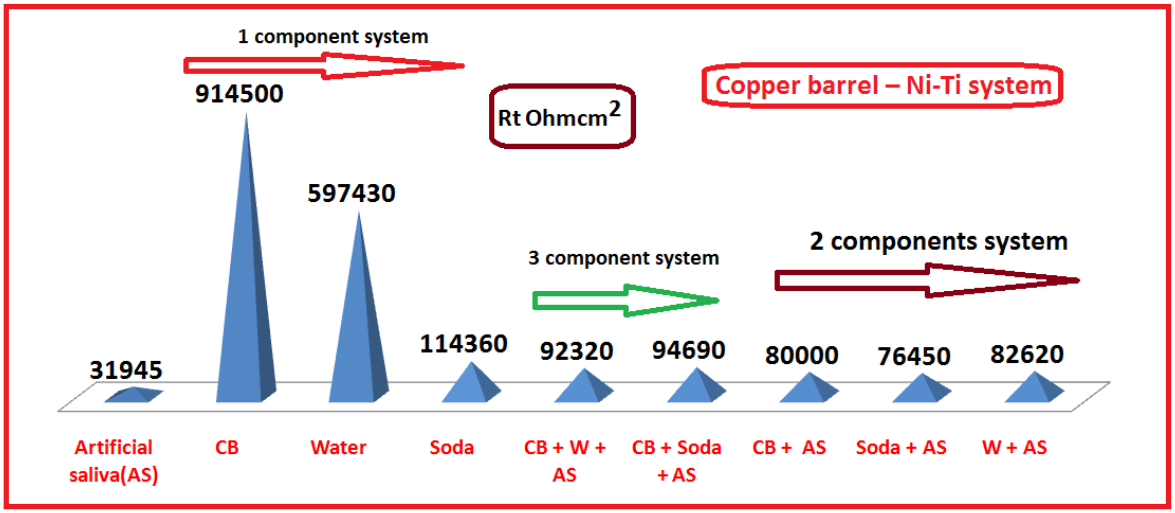
*Conclusion*

The people who have been clipped with ortho-dontic wire made of Ni-Ti alloy can takecopper barrel in any form namely, with dilution or without dilution.

*Table 1. Corrosion Parameters of Ni-Ti alloy immersed in various test solutions containing Copper Barrel obtained by AC Impedance spectra*

*Tabela 1. Parametri korozije legure Ni-Ti uronjene u različite test rastvore koji sadrže žestoko piće Copper Barrel dobijeno spektrom AC impedanse*

| System | $R_t$, Ohmcm$^2$ | $C_{dl}$, F/cm$^2$ | Impedance, Log(Z/ohm) |
|---|---|---|---|
| **Artificial saliva(AS)** | 31945 | $1.596 \times 10^{-10}$ | 4.649 |
| **CB** | 914500 | $1.9227 \times 10^{-11}$ | 6.047 |
| **Water** | 597430 | $4.0050 \times 10^{-11}$ | 5.913 |
| **Soda** | 114360 | $3.001 \times 10^{-10}$ | 5.455 |
| **CB + W + AS** | 92320 | $3.8054 \times 10^{-10}$ | 5.405 |
| **CB + Soda + AS** | 94690 | $4.0666 \times 10^{-10}$ | 5.4 |
| **CB + AS** | 80000 | $4.5929 \times 10^{10}$ | 5.383 |
| **Soda + AS** | 76450 | $4.8864 \times 10^{-10}$ | 5.373 |
| **W + AS** | 82620 | $4.5797 \times 10^{-10}$ | 5.375 |




*Scheme A. Comparison of Corrosion Parameters of Ni-Ti alloy immersed in various test solutions containing Copper Barrel obtained by AC Impedance spectra*

*Šema A. Poređenje parametara korozije legure Ni-Ti uronjene u različite test rastvore,koji sadrže žestoko piće Copper Barrel, dobijeno spektrom naizmenične impedanse*

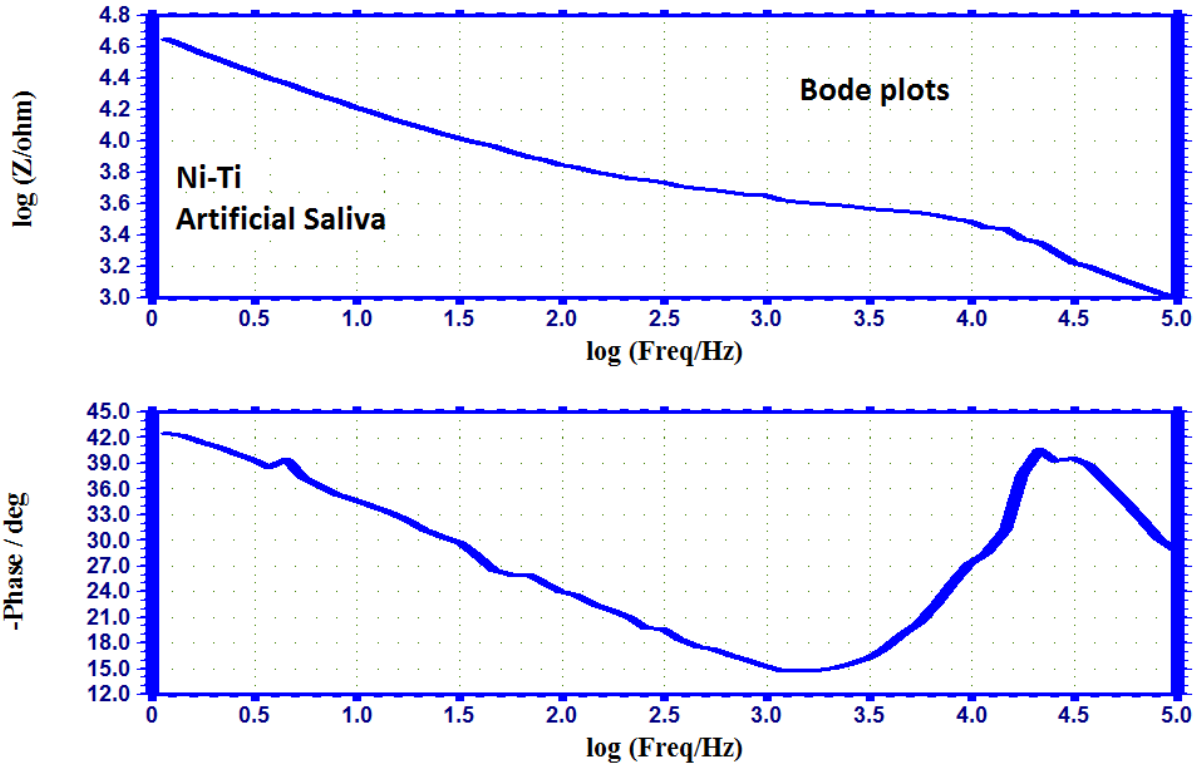



*Figure 1. Bode plots of Ni-Ti alloy immersed in Artificial Saliva*

*Slika 1. Bode-ove krive legure Ni-Ti uronjene u veštačku pljuvačku*

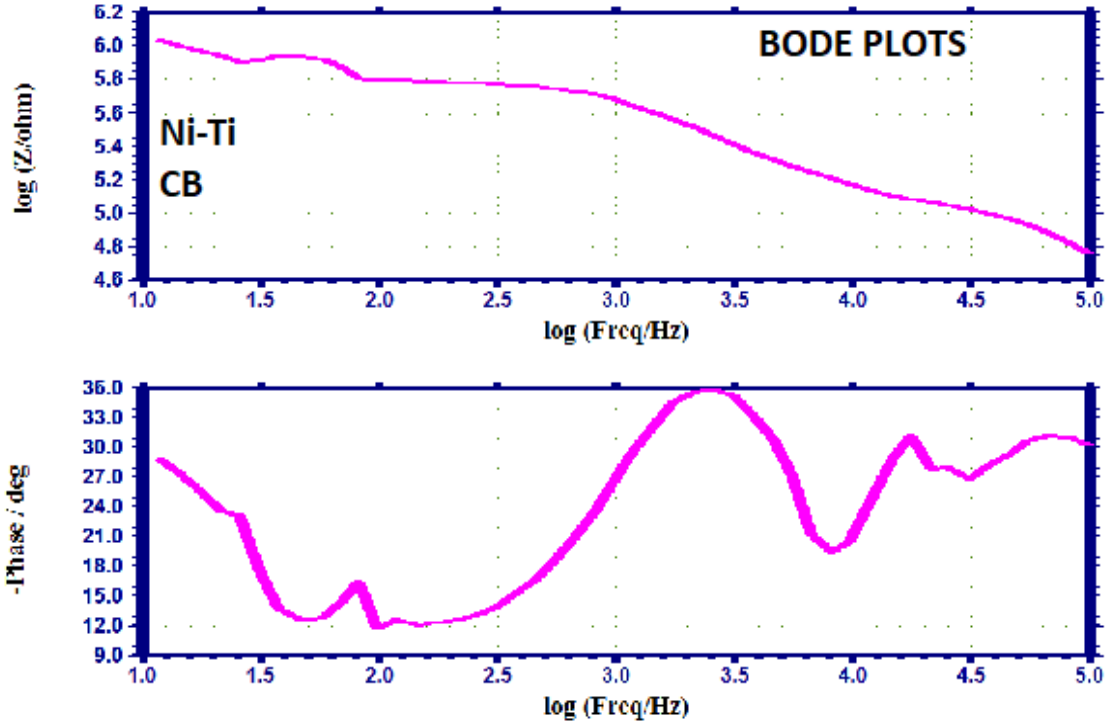



*Figure 2. Bode plots of Ni-Ti alloy immersed in Copper barrel*

*Slika 2. Bode-ove krive legure Ni-Ti uronjene u žestoko piće Copper barrel*

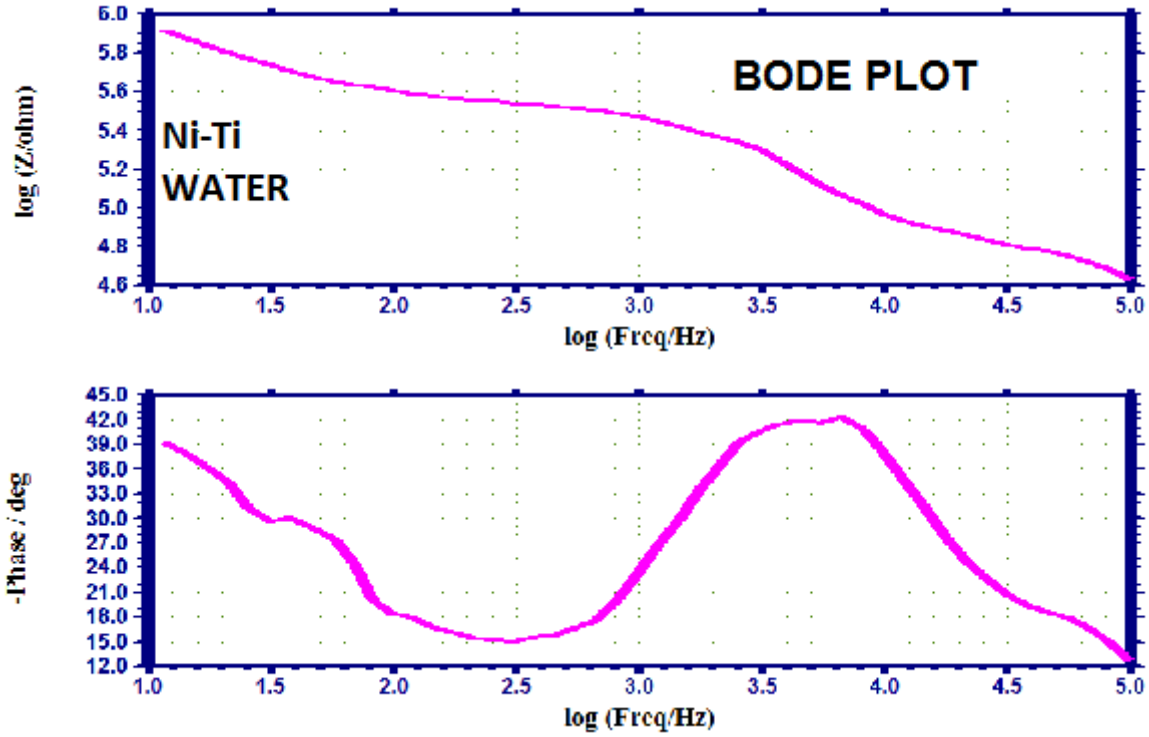



*Figure 3. Bode plots of Ni-Ti alloy immersed in Bisleri water*

*Slika 3. Bod-ove krive legure Ni-Ti uronjene u vodu Bisleri*

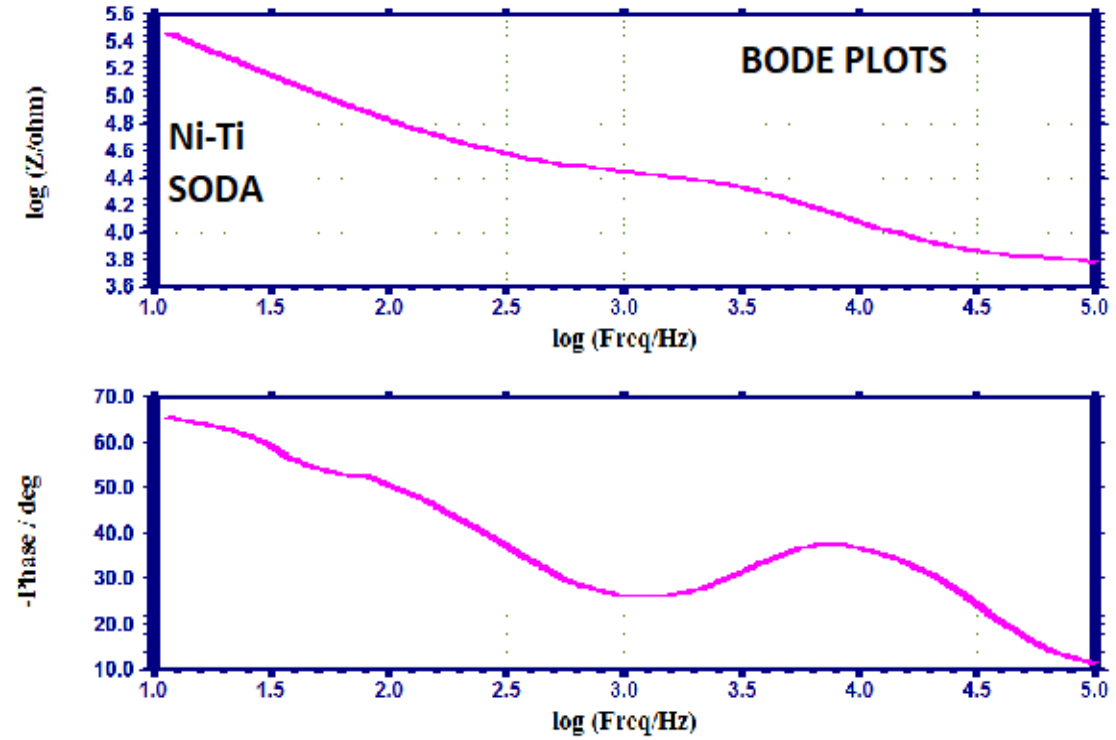



*Figure 4. Bode plots of Ni-Ti alloy immersed in Soda water*

*Slika 4. Bode-ove krive legure Ni-Ti uronjene u Soda vodu*

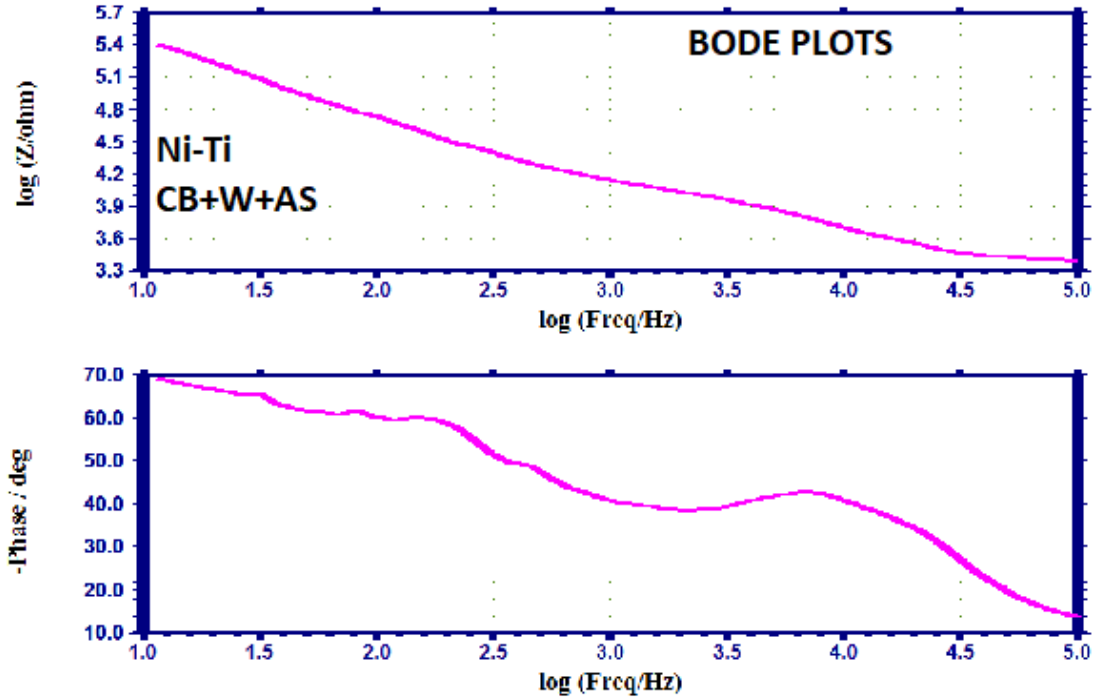



*Figure 5. Bode plots of Ni-Ti alloy immersed in Copper barrel + Bisleri water + Artificial saliva*

*Slika 5. Bode-ove krive legure Ni-Ti uronjene u žestoko piće Copper barrel + Bisleri voda + veštačka pljuvačka*

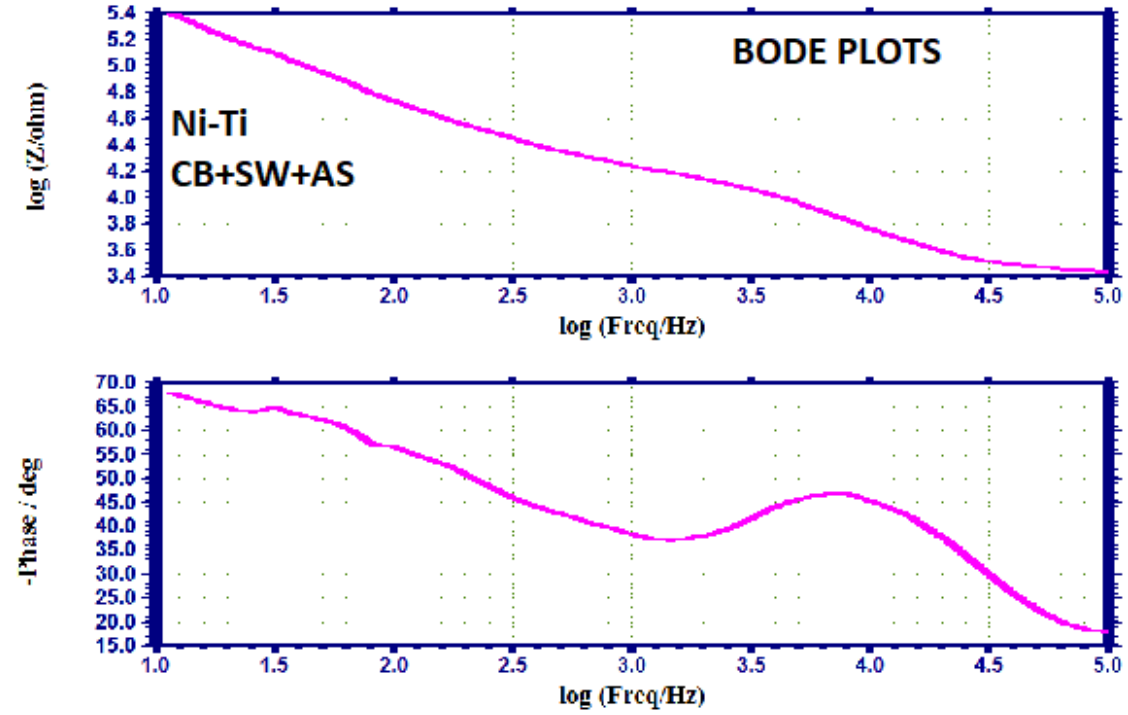



*Figure 6. Bode plots of Ni-Ti alloy immersed in Copper barrel + Soda water + Artificial saliva*

*Slika 6. Bode-ove krive legure Ni-Ti uronjene u žestoko piće Copper barrel + Soda voda + veštačka pljuvačka*

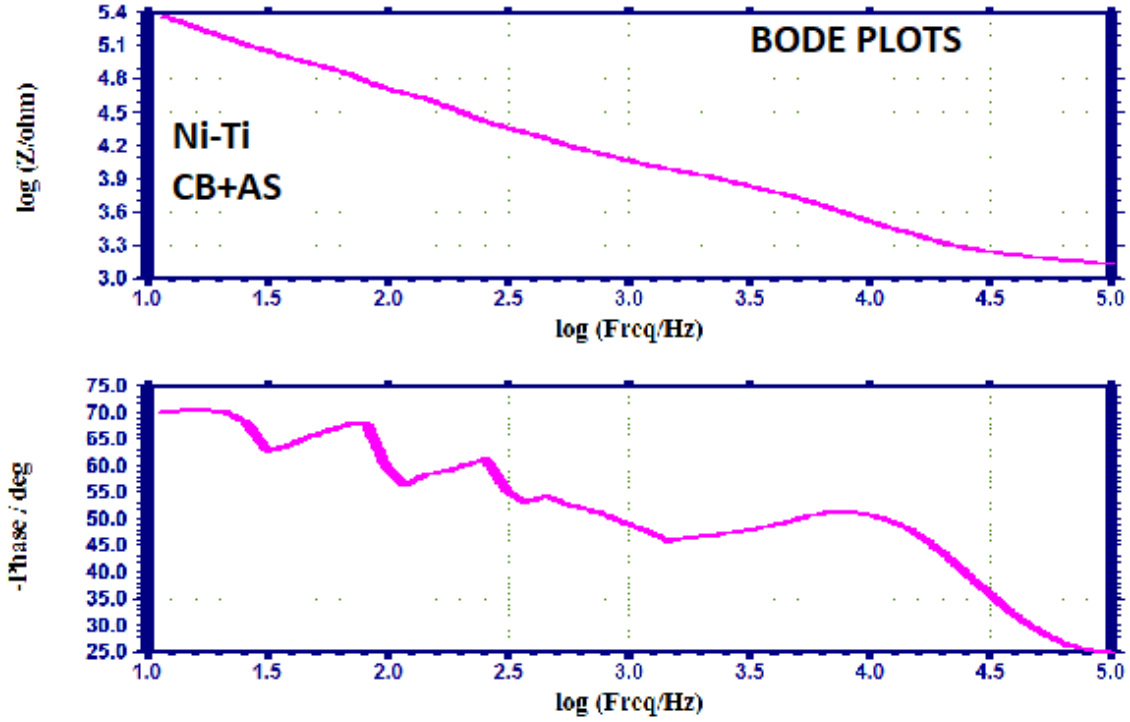



*Figure 7. Bode plots of Ni-Ti alloy immersed in Copper barrel + Artificial saliva*

*Slika 7. Bode-ove krive legure Ni-Ti uronjene u žestoko piće Copper barrel + veštačka pljuvačka*

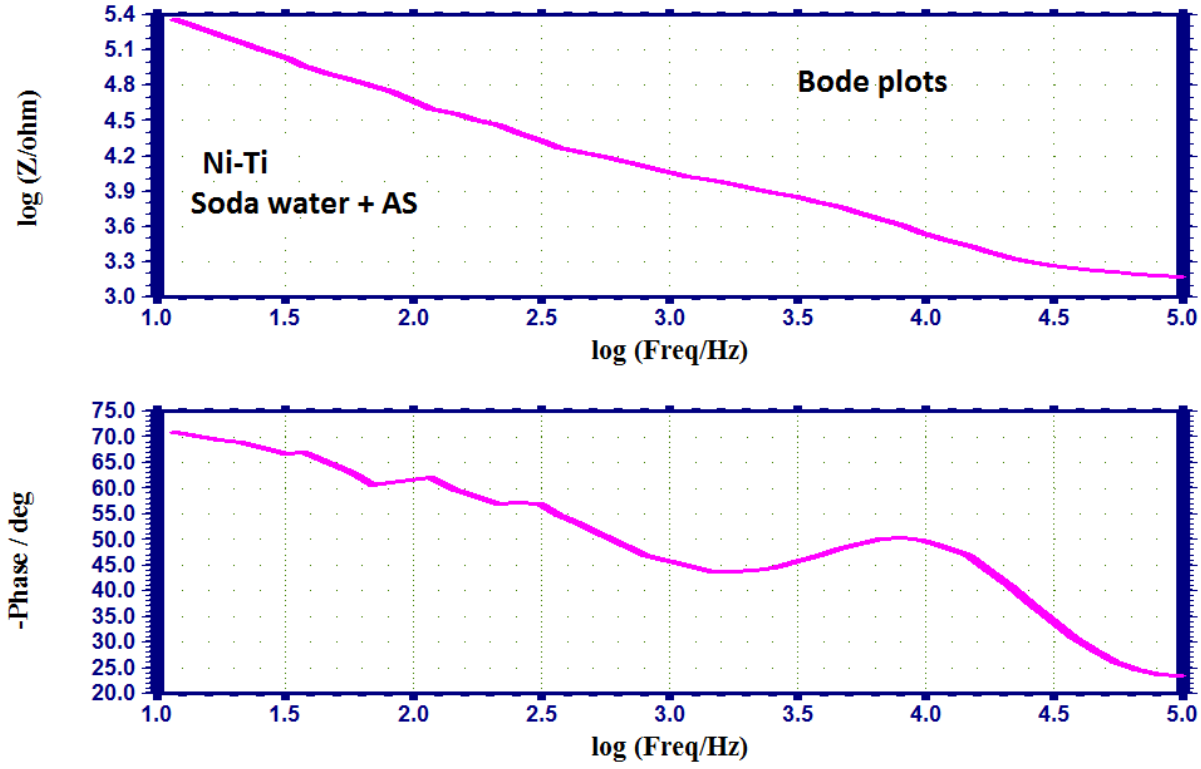



*Figure 8. Bode plots of Ni-Ti alloy immersed in Soda water + Artificial saliva*

*Slika 8. Bode-ove krive legure Ni-Ti uronjene u Soda voda + veštačka pljuvačka*

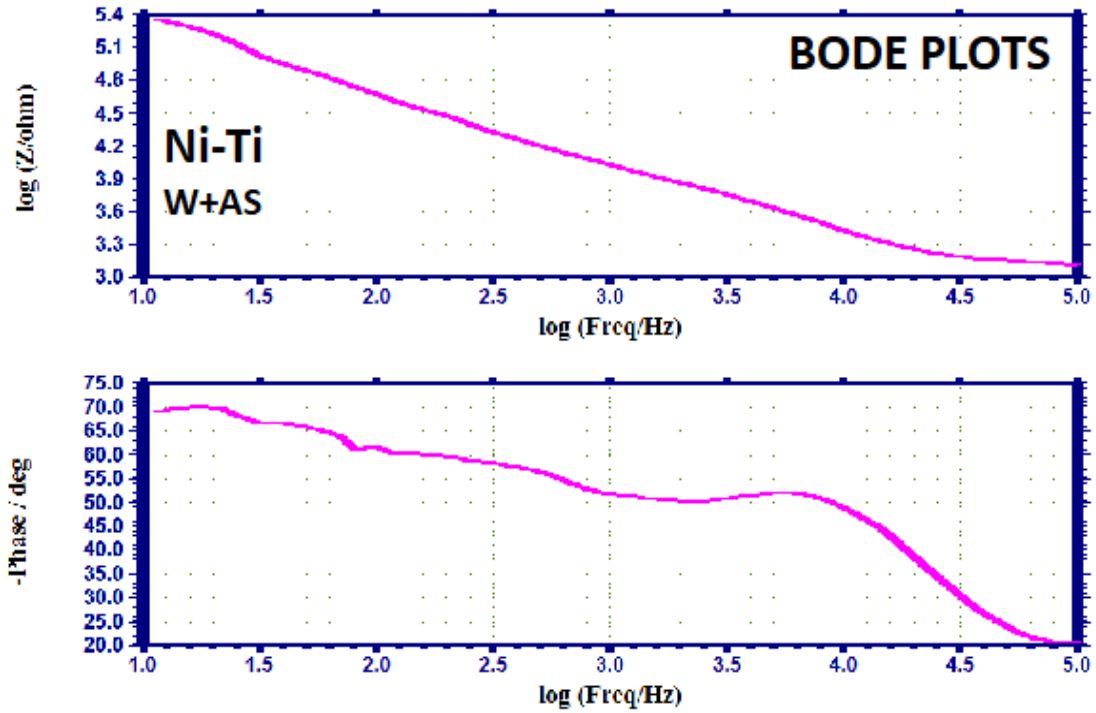



*Figure 9. Bode plots of Ni-Ti alloy immersed in Bisleri water + Artificial saliva*

*Slika 9. Bode-ove krive legure Ni-Ti uronjene u Bisleri voda + veštačka pljuvačka*

*Ni-Cr alloy system*

Corrosion resistance of orthodontic wire made of Ni-Ti alloy in artificial saliva in the absence and presence of Copper barrel , water and soda water has been evaluated by AC impedance spectra. The results are shown in Table 2, Scheme B and Fig. 10-18. When corrosion resistance increases $R_t$ (Charge transfer resistance) value increases, impedance increases and double layer capacitance ($C_{dl}$) decreases. On the other hand, when corrosion resistance decreases $R_t$ (Charge transfer resistance) value decreases, impedance decreases and double layer capacitance ($C_{dl}$) increases.

*One component system*

When Ni-Cr alloy is immersed in one component system, namely,copper barrel or water or soda water(in the absence of artificial saliva) the corrosion resistances are as follows (Table2):

Copper barrel > water >artificial saliva>soda water

*Three component system*

When Ni-Cr alloy is immersed in three component system, namely,copper barrel , water and soda water the corrosion resistances are as follows (Table2):

*AS > CB + W + AS > CB + Soda + AS*

*Implication*

When copper barrel is mixed with soda water, corrosion resistance of Ni-Cr alloy in artificial saliva , is found to be less than that of the system consisting of copper barrel and water in the presence of artificial saliva. The corrosion resistance of the two systems are lower than that of the AS system. It is interesting to note that, in the above two systems, corrosion resistance of Ni-Cr alloy in artificial saliva , is found to decrease. Hence it is concluded that people having clipped with orthodontic wire made of Ni-Cr alloy should avoid taking CB + W or CB + Soda orally.

*Two component system*

When copper barrel alone or soda water alone or water alone, is orally intaken, corrosion resistance of Ni-Cr alloy in artificial saliva is as follows (Table 2):

Artificial saliva > water alone >copper barrel alone > soda water alone

*Implication*

Copper barrel alone or water alone or soda water alone should not be taken orally , by the people who have been clipped with orthodontic wire made of Ni-Cr alloy.

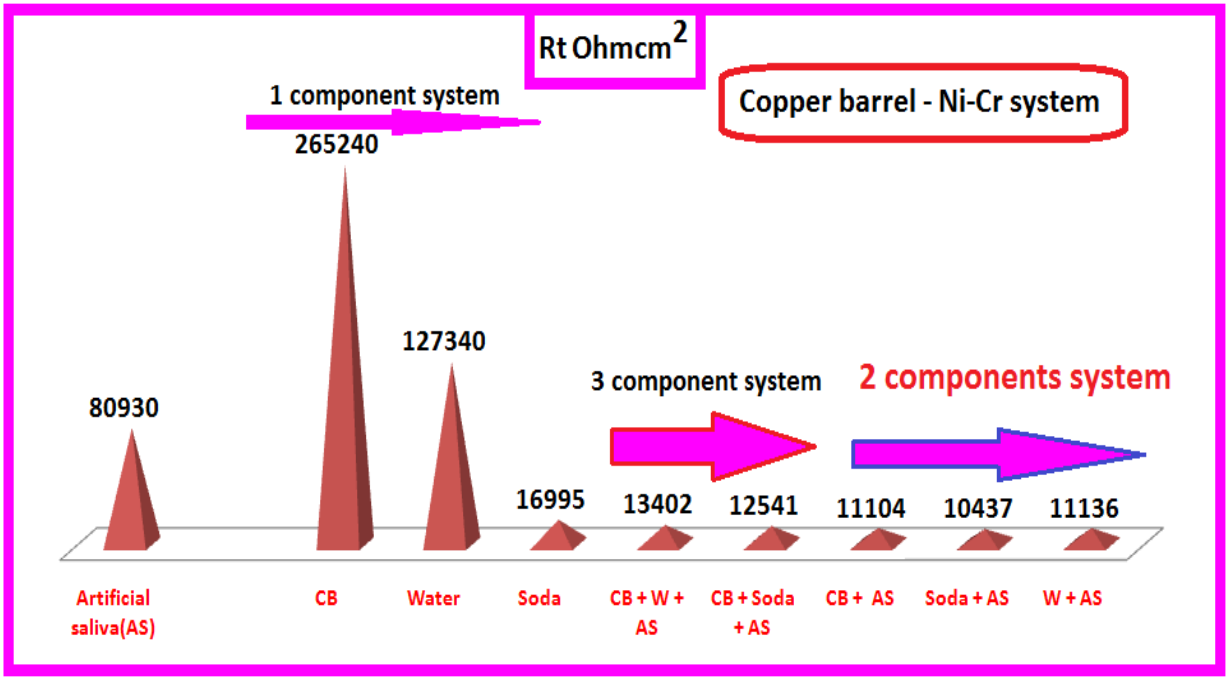
*Conclusion*

The people who have been clipped with orthodontic wire made of Ni-Cr alloy should avoid taking copper barrel in any form namely, with dilution or without dilution.

*Table 2. Corrosion Parameters of Ni-Cr alloy immersed in various test solutions containing Copper Barrel obtained by AC Impedance spectra*

*Tabela 2. Parametri korozije Ni-Cr legure potopljene u različite test rastvore koji sadrže žestoko piće Copper Barrel dobijeno spektrom AC impedanse*

| System | $R_t$, Ohmcm$^2$ | $C_{dl}$, F/cm$^2$ | Impedance,Log(Z/ohm) |
|---|---|---|---|
| **Artificial saliva(AS)** | 80930 | 6.301 x10$^{-11}$ | 5.239 |
| **CB** | 265240 | 1.923 x10$^{-11}$ | 5.474 |
| **Water** | 127340 | 4.005 x10$^{-11}$ | 5.172 |
| **Soda** | 16995 | 3.001 x10$^{-10}$ | 4.496 |
| **CB + W + AS** | 13402 | 3.805 x10$^{-10}$ | 4.444 |
| **CB + Soda + AS** | 12541 | 4.067 x10$^{-10}$ | 4.385 |
| **CB + AS** | 11104 | 4.593 x10$^{-10}$ | 4.383 |
| **Soda + AS** | 10437 | 4.887 x10$^{-10}$ | 4.361 |
| **W + AS** | 11136 | 4.580 x10$^{-10}$ | 4.292 |




*Scheme B. Comparison of Corrosion Parameters of Ni-Cr alloy immersed in various test solutions containing Copper Barrel obtained by AC Impedance spectra*

*Šema B. Poređenjeparametarakorozijelegure Ni-Cruronjene u različite test rastvore,kojisadržežestokopiće Copper Barrel,dobijenespektromnaizmeničneimpedanse*

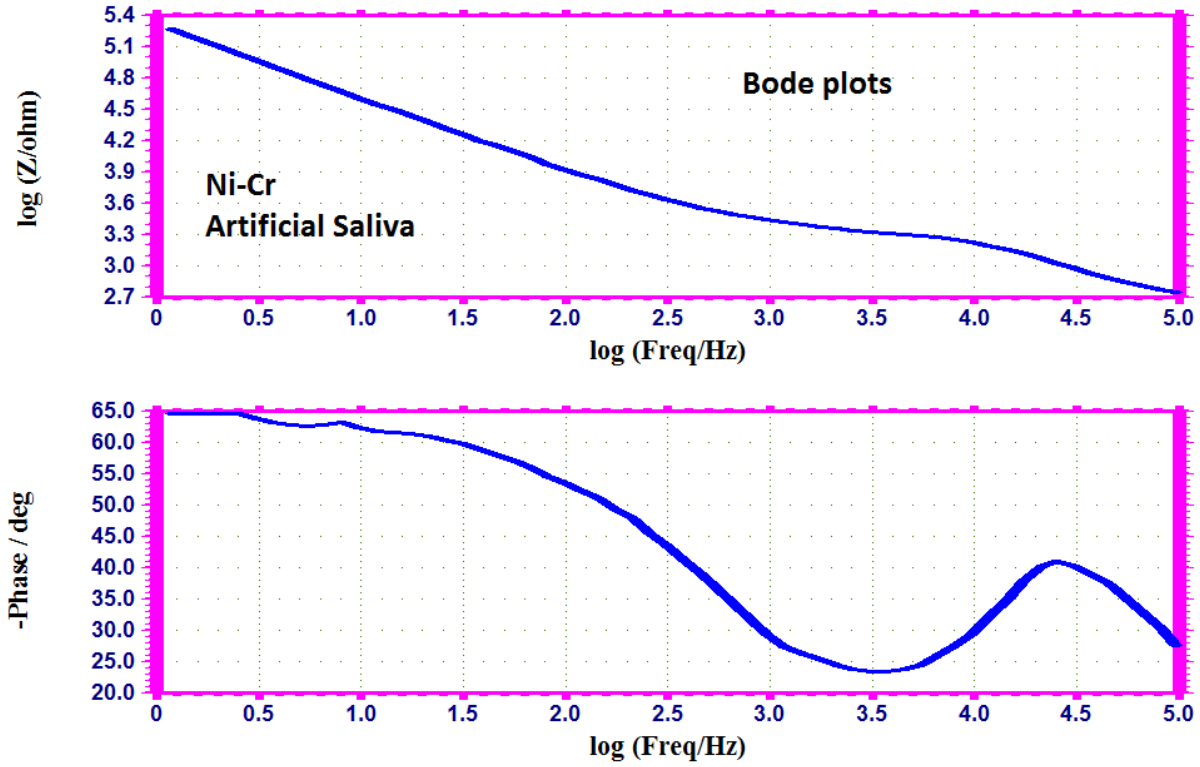



*Figure 10. Bode plots of Ni-Cr alloy immersed in Artificial saliva*

*Slika 10. Bode-ove krive legure Ni-Cr uronjene u veštačku pljuvačku*

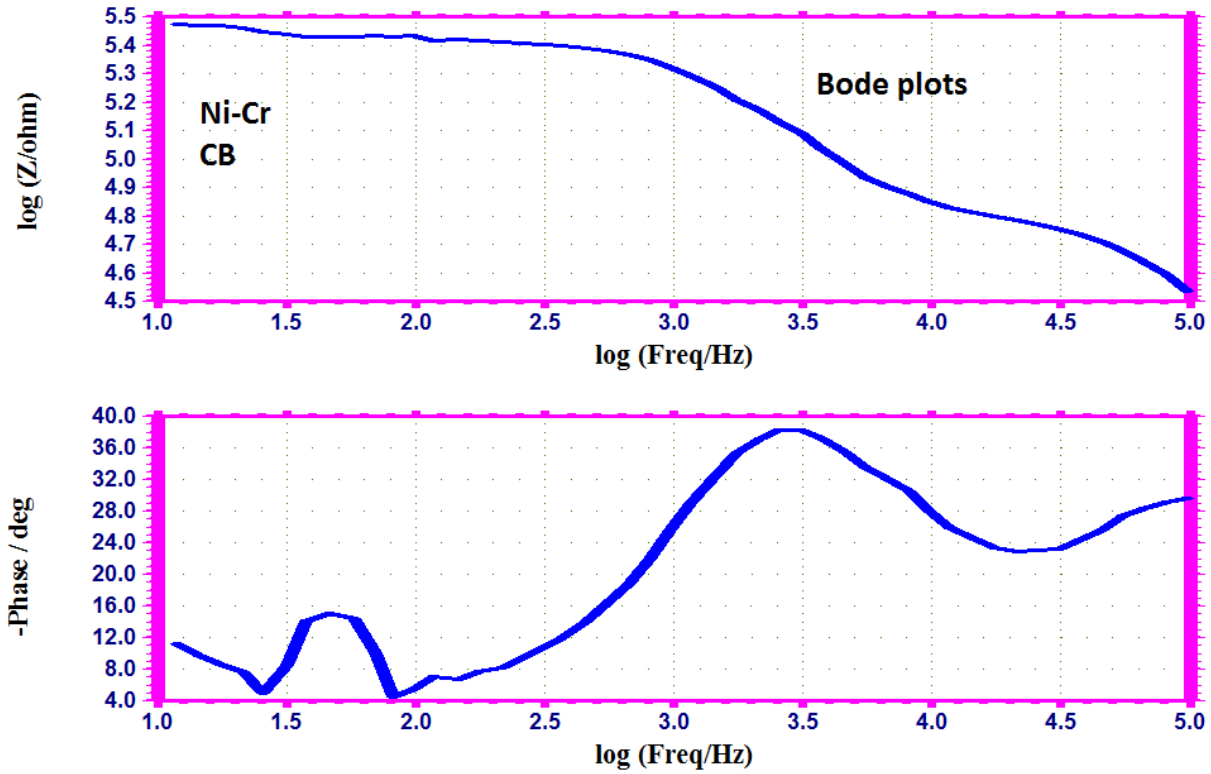



*Figure 11. Bode plots of Ni-Cr alloy immersed in Copper Barrel*

*Slika 11. Bode-ove krive legure Ni-Cr uronjene u žestoko piće Copper Barrel*

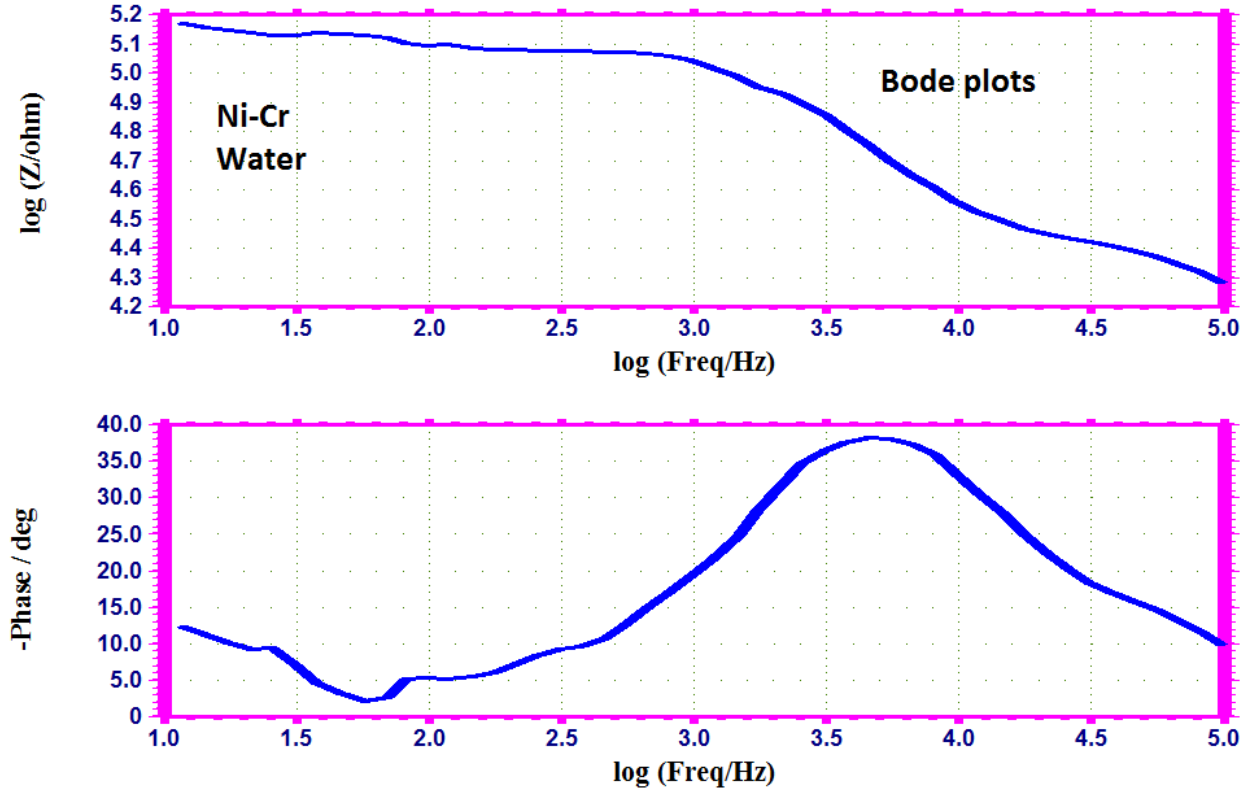



*Figure 12. Bode plots of Ni-Cr alloy immersed in Bisleri water*

*Slika 12. Bode-ove krive legure Ni-Cr uronjene u vodu Bisleri*

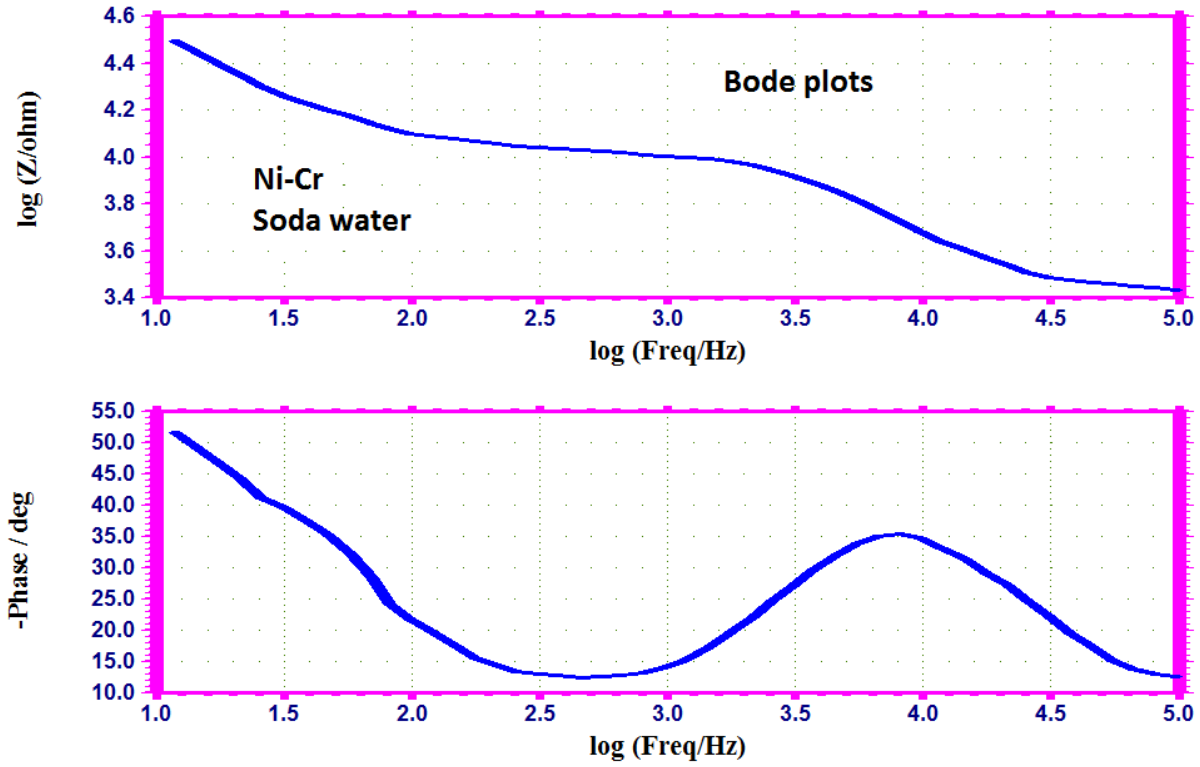



*Figure 13. Bode plots of Ni-Cr alloy immersed in Soda water*

*Slika 13. Bode-ove krive legure Ni-Cr uronjene u Soda vodu*

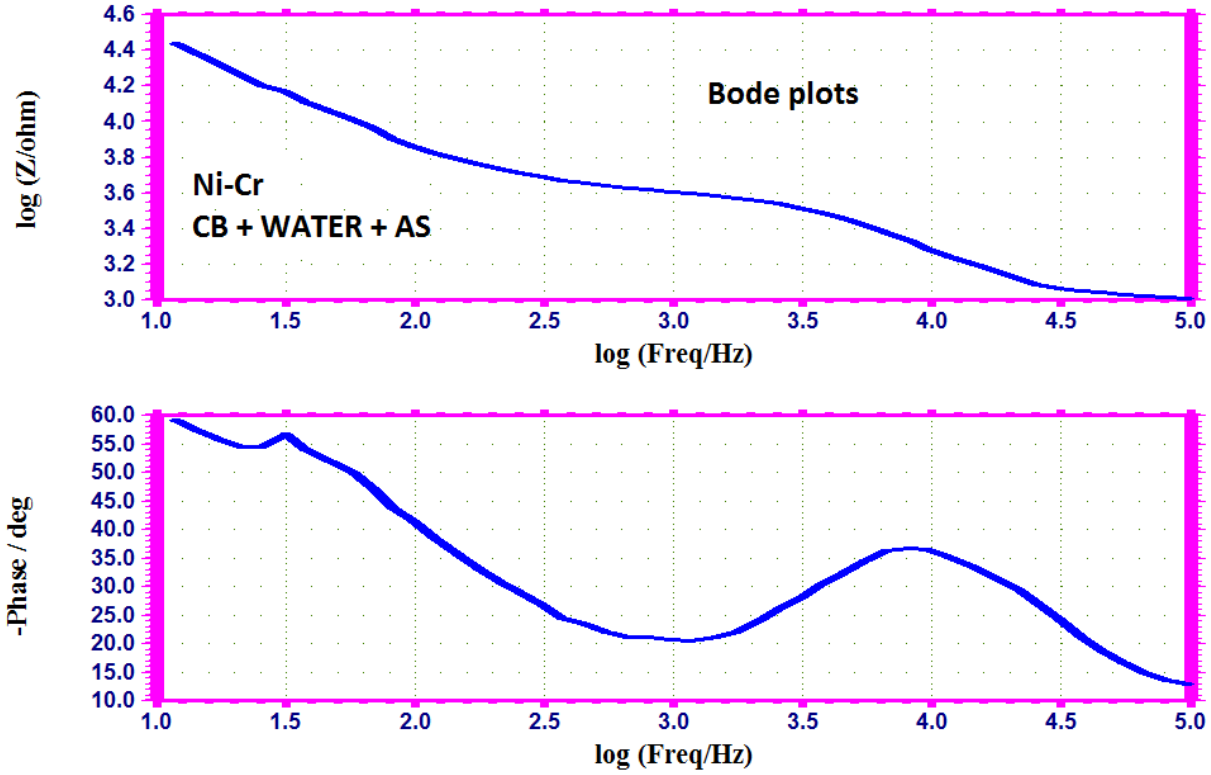



*Figure 14. Bode plots of Ni-Cr alloy immersed in CB + water+ AS*

*Slika 14. Bode-ove krive legure Ni-Cr uronjene u žestoko piće Copper barrel + voda + veštačka pljuvačka*

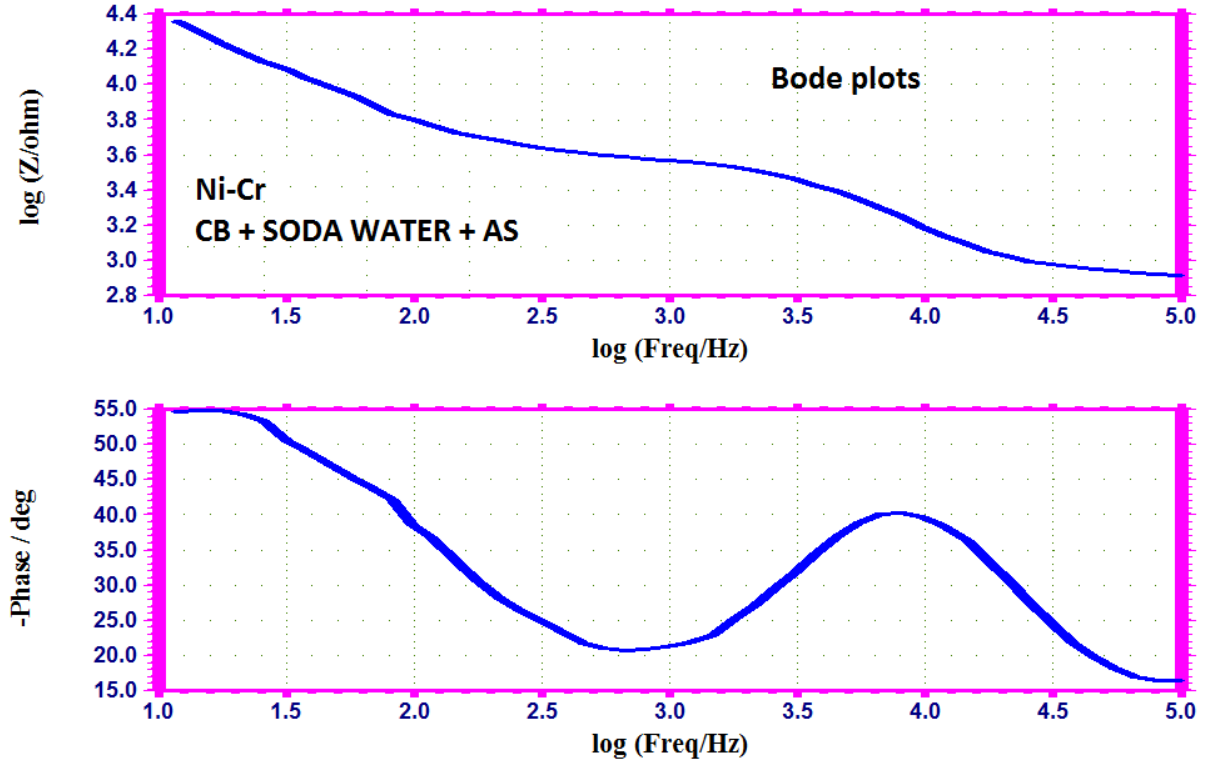



*Figure 15.Bode plots of Ni-Cr alloy immersed in CB + Soda water+ AS*

*Slika 15. Bode-ove krive legure Ni-Cr uronjene u žestoko piće Copper barrel + Soda voda + veštačka pljuvačka*

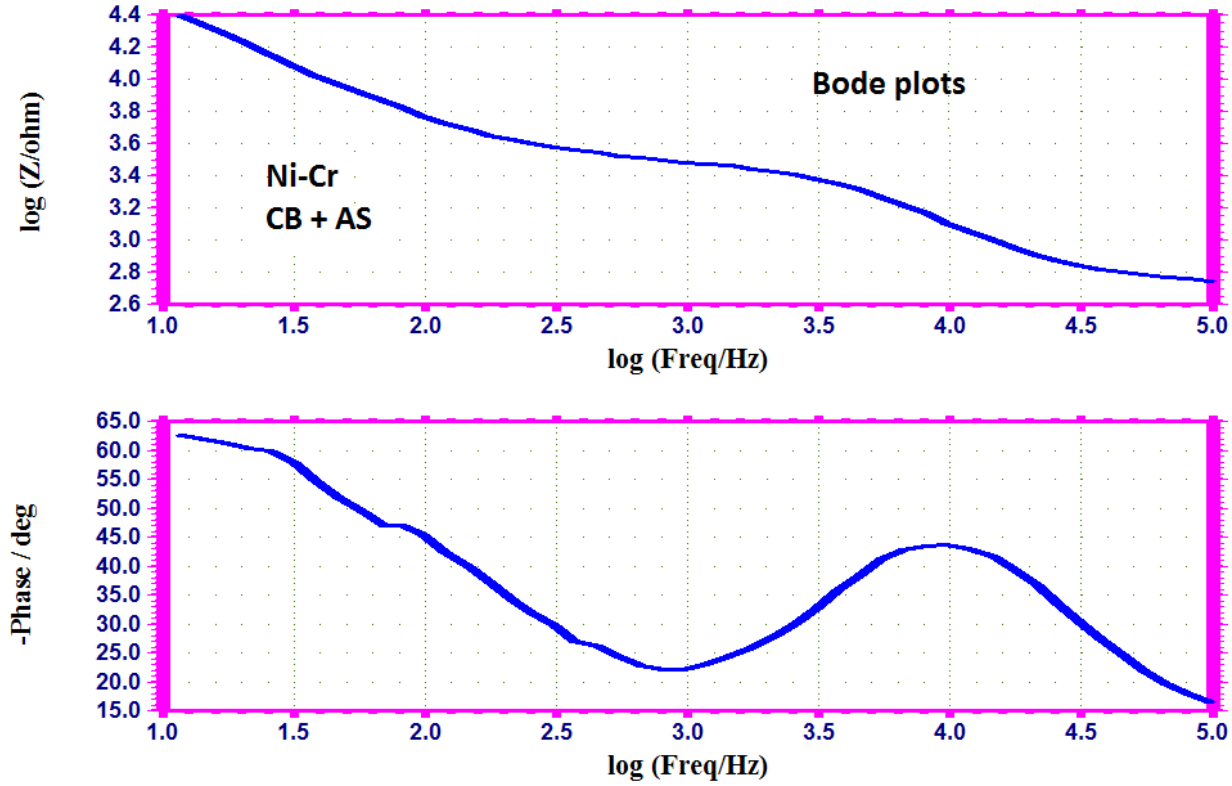



*Figure 16. Bode plots of Ni-Cr alloy immersed in CB + AS*

*Slika 16. Bode-ove krive legure Ni-Cr uronjene u žestoko piće Copper barrel + veštačka pljuvačka*

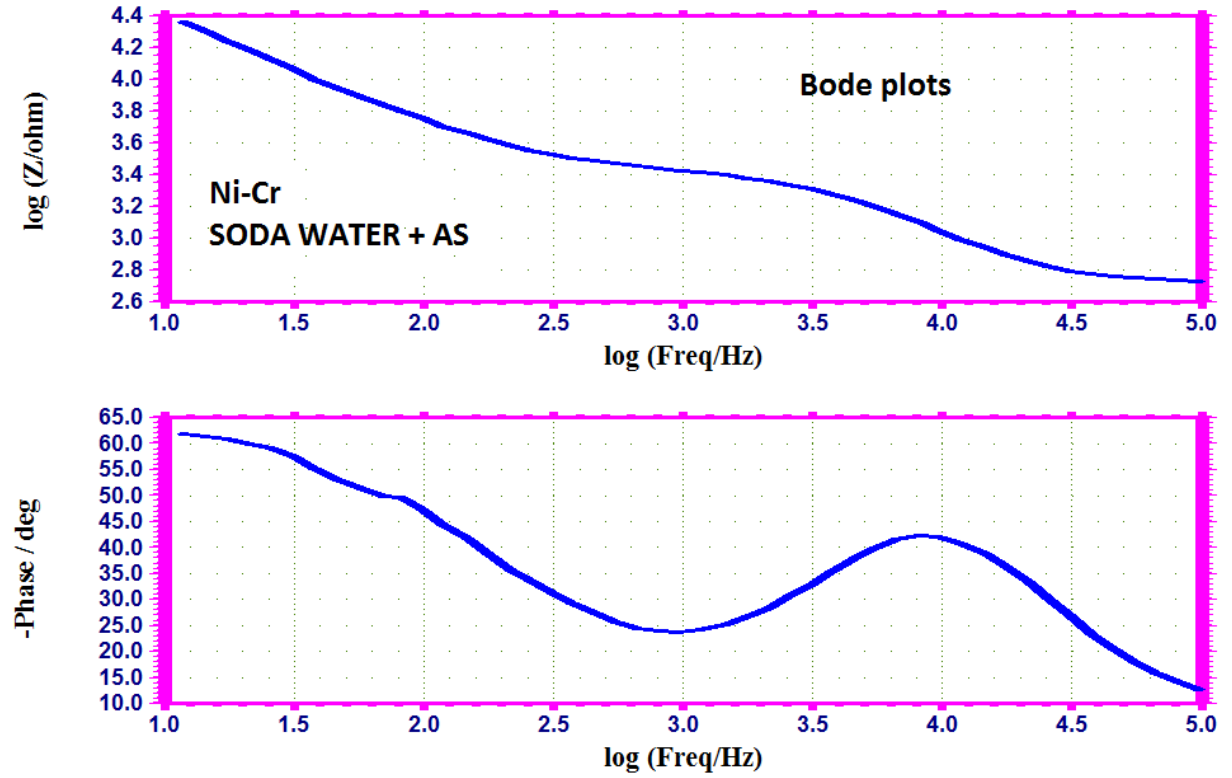



*Figure 17. Bode plots of Ni-Cr alloy immersed in Soda water + AS*

*Slika 17. Bode-ove krive legure Ni-Cr uronjene u Soda voda + veštačka pljuvačka*

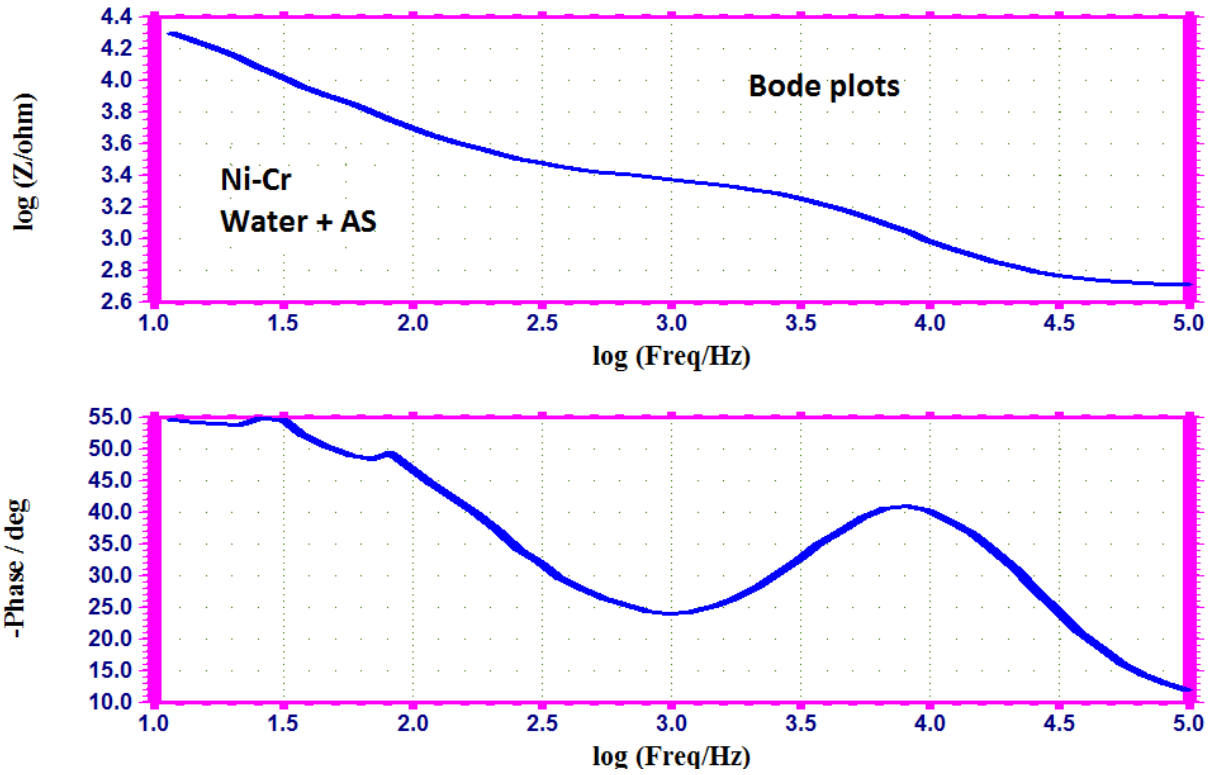



*Figure 18. Bode plots of Ni-Cr alloy immersed in water + AS*

*Slika 18. Bode-ove krive legure Ni-Cr uronjene u voda + veštačka pljuvačka*

## 4. CONCLUSIONS

- The people who have been clipped with orthodontic wire made of Ni-Ti alloy can take copper barrel in any form, namely, with dilution or without dilution using water or soda water.
- The people who have been clipped with orthodontic wire made of Ni-Cr alloy should avoid taking copper barrel in any form, namely, with dilution or without dilution using water or soda water.

*Acknowledgement*

*The authors are thankful to TNSCST, DOTE campus Chennai, India for their help and support.*

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## IZVOD

### UTICAJ RAZBLAŽIVANJA I DODAVANJA SODA VODE NA OTPORNOST NA KOROZIJU ORTODONTSKIH ŽICA POTOPLJENIH U VEŠTAČKU PLJUVAČKU U PRISUSTVU COPPER BARREL-A, ŽESTOKOG PIĆA

*Žestoko piće Copper Barrel može se uzimati oralno sa razblaženjem soda vodom i bez razblaživanja. Ljudi, koji u ustima maju ortodontske žice, koriste ovo žestoko piće oralno, uz razblaživanje i bez razblaživanja. Koliko će ovo piće uticati na ortodontske žice? U cilju pronalaženja odgovora uradjen je ovaj istraživački rad. Otpornost na koroziju ortodontskih žica od legure Ni-Ti i legure Ni-Cr u veštačkoj pljuvački u odsustvu i prisustvu rakije, vode i soda vode je procenjena spektrima AC impedanse. Generalno se primećuje da je legura Ni-Ti otpornija na koroziju od legure Ni-Cr u veštačkoj pljuvački u prisustvu navedenog žestokog pića, vode i soda vode. Kada se ortodontska žica napravljena od Ni-Ti uroni u veštačku pljuvačku, vrednost otpora prenosa naelektrisanja (Rt) iznosi 31945 Ohmcm$^2$. Kada je legura uronjena u žestoko piće + sistem veštačke pljuvačke (AS), vrednost Rt se povećavana 80000 Ohmcm$^2$. Kada je uronjen u sistem soda voda + veštačka pljuvačka (AS), vrednost Rt se povećavana 76450 Ohmcm$^2$. Kada je uronjen u sistem voda + veštačka pljuvačka (AS), vrednost Rt se povećava na 82620 Ohmcm$^2$. S druge strane, kada se ortodontska žica napravljena od legure Ni-Cr uroni u veštačku pljuvačku, vrednost otpora prenosa naelektrisanja (Rt) iznosi 80930 Ohmcm$^2$. Kada je legura uronjena u žestoko piće + sistem veštačke pljuvačke (AS), vrednost Rt se smanjuje na 11104 Ohmcm$^2$. Kada se potopi u sistem soda voda + veštačka pljuvačka (AS), vrednost Rt se smanjuje na 10437 Ohmcm$^2$. To podrazumeva da ljudi koji su imali u ustima ortodontskužicu od Ni-Ti legure mogu da uzimaju navedeno žestoko piće u bilo kom obliku, sa razblaženjem ili bez razblaživanja. Osobe koje su imale u ustima ortodontsku žicu od legure Ni-Cr treba da izbegavaju uzimanje navedenog žestokog pića u bilo kom obliku, sa razblaženjem ili bez razblaženja.*

***Ključne reči:*** *ortodontske žice, otpornost na koroziju, soda voda, veštačka pljuvačka, žestoko piće, Ni-legure*

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