



# **ELECTROCHEMICAL STUDY ON CORROSION INHIBITION OF METALS IN ARTIFICIAL URINE IN PRESENCE OF SODIUM CHLORIDE**

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## **ABSTRACT**

The main aim of the research was evaluation of corrosion resistance of SS 316L, NiTi alloy in artificial urine in presence of sodium chloride. Corrosion resistance of two metals namely SS 316L, Nickel Titanium super elastic alloy has been evaluated in artificial urine (AU) in the absence and presence of sodium chloride. Potentiodynamic polarization study and SEM have been used to investigate the corrosion behavior of these metals and nature of the protective film formed on the metal surface. The order of corrosion resistance of metals in artificial urine, in the absence and also in the presence of sodium chloride was discussed.

**Key words:** SS 316L, Nickel titanium super elastic alloy, Artificial urine, Sodium chloride.

## **INTRODUCTION**

Metallic biomaterials are commonly used in reconstruction in the orthopedic and dental surgery, operative cardiology and urology. Stainless steels, titanium alloys and cobalt alloys are commonly used as biomaterials<sup>1,2</sup>. Nowadays NiTi shape memory alloys are also introduced to clinical practice. The major advantage of these biomaterials refers to their unique properties. When shape memory alloys are considered as candidates to be applied in medical devices, they must be able to fulfill functional requirements related not only to their mechanical reliability but also to their chemical reliability and their biological reliability.

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The corrosion resistance of the biomaterial decides the reactivity of implants in the environment of tissues and organism fluids. Good biocompatibility is observed for metal and alloys with the high anode potential<sup>3</sup>. Corrosion type and its intensity depend on the chemical composition of the material, load type, implants geometrical shape, and the operation technique. The present work was under taken 1. To study the corrosion behavior of two metals namely SS 316L, Nickel Titanium super elastic alloy are immersed in artificial urine in presence of sodium chloride by Potentiodynamic polarization study. 2. To analyse the protective film by SEM.

## EXPERIMENTAL

### Materials and methods

Two metals namely SS 316L, nickel titanium super elastic alloy were chosen for the present work. The composition of SS 316 L was (wt%) 18Cr, 12Ni, 2.5Mo, <0.03C and the balance iron. The composition of Ni-Ti super elastic alloy was (wt %) Ni 55.5, and balance Ti.<sup>4</sup> The metal specimens were encapsulated in Teflon. The surface area of the exposed metal surface was 0.0785 cm<sup>2</sup>. The metal specimens were polished to mirror finish and degreased with trichloroethylene. The metal specimens were immersed in artificial urine (AU), whose composition was: Solution A: CaCl<sub>2</sub>.H<sub>2</sub>O – 1.765 g/L, Na<sub>2</sub>SO<sub>4</sub> – 4.862 g/L, MgSO<sub>4</sub>.7H<sub>2</sub>O – 1.462 g/L, NH<sub>4</sub>Cl – 4.643 g/L, KCl – 12.130 g/L. Solution B: NaH<sub>2</sub>PO<sub>4</sub>.2H<sub>2</sub>O – 2.660 g/L, Na<sub>2</sub>HPO<sub>4</sub> – 0.869 g/L, C<sub>6</sub>H<sub>5</sub>Na<sub>3</sub>O<sub>7</sub>.2H<sub>2</sub>O – 1.168 g/L, NaCl – 13.545 g/L. The pH of the solution was 6.5<sup>5</sup>. In electrochemical studies the metal specimens were used as working electrodes. AU was used as the electrolyte (10 mL). The temperature was maintained at 37 ± 0.1°C.

### Potentiodynamic polarization

Potentiodynamic polarization studies were carried out using a CHI electrochemical impedance analyzer, model 660 A. A three electrode cell assembly was used. The working electrode was a rectangular specimen of one of the two metals with one face of the electrode (1 cm<sup>2</sup> area) exposed and the rest shielded with red lacquer. A saturated calomel electrode (SCE) was used as the reference electrode and a rectangular platinum foil was used as the counter electrode. Polarization curves were recorded using iR compensation. During the polarization study, the scan rate (v/s) was 0.01, hold time at E<sub>f</sub>(s) was zero, and quit time(s) was 2.

### Scanning electron microscopic studies (SEM)

The metal specimen immersed in artificial urine solution for a period of one day was

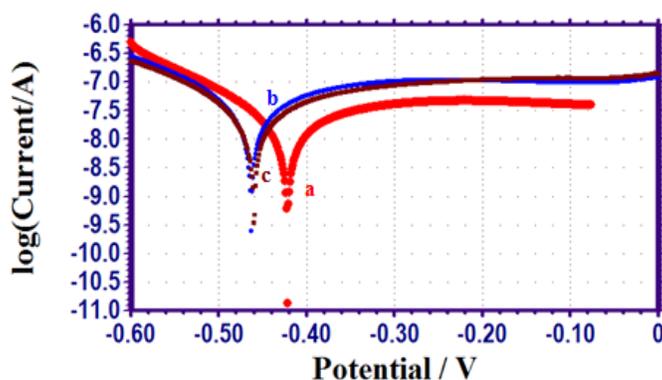
removed, rinsed with double-distilled water, dried, and observed in a scanning electron microscope to examine the surface morphology. The surface morphology measurements of the metals were examined using JOEL-6390 computer-controlled scanning electron microscope.

## RESULTS AND DISCUSSION

### Polarization study

#### Corrosion resistance of SS 316L in artificial urine in presence of sodium chloride

Polarization study has been used to confirm the formation of protective film formed on the metal surface during corrosion inhibition process. The polarization curve of SS 316L immersed in AU in the absence and presence of sodium chloride is shown in Fig. 1. The corrosion parameters such as corrosion potential ( $E_{\text{Corr}}$ ), Tafel slopes (anodic slope  $b_a$  and cathodic slope  $b_c$ ), linear polarization resistance and corrosion current ( $I_{\text{Corr}}$ ) values were calculated and are given in Table 1. It is observed from Table 1 that when 50 ppm of sodium chloride is added to AU, the LPR value decreases from  $1.68 \times 10^6$  to  $8.89 \times 10^5$  ohm $\text{cm}^2$  and the corrosion current ( $I_{\text{Corr}}$ ) increases from  $2.40 \times 10^{-8}$  to  $4.70 \times 10^{-8}$  A/ $\text{cm}^2$ . When 100 ppm of sodium chloride is added to AU, the LPR value increases to  $1.10 \times 10^6$  ohm $\text{cm}^2$  and the corrosion current ( $I_{\text{Corr}}$ ) decreases to  $3.37 \times 10^{-8}$  A/ $\text{cm}^2$ . In general it is observed that the corrosion resistance of SS 316 L in AU decreases in the presence of 50 ppm of sodium chloride and increases in the presence of 100 ppm of sodium chloride<sup>6</sup>. It is observed from the table that the corrosion potential shifts to anodic side (less negative) in the presence of sodium chloride. Hence it is concluded that in presence of sodium chloride, the anodic reaction is controlled predominantly.



**Fig. 1: Polarization curves of SS 316 L in various test solutions (a) AU (b) AU + 50 ppm of sodium chloride (c) AU + 100 ppm of sodium chloride**

**Table 1: Corrosion parameters of SS 316 L immersed in AU in absence and presence of sodium chloride obtained by polarization study**

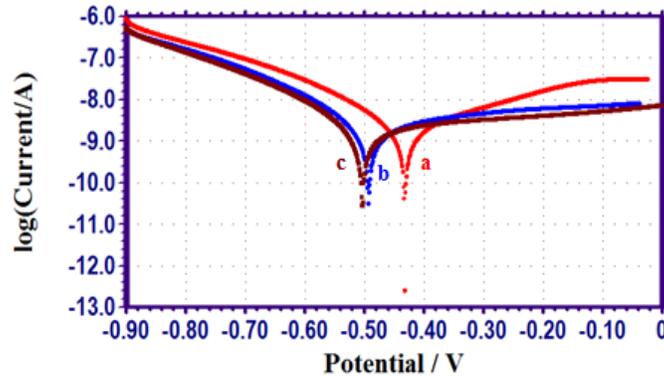
System	$E_{\text{corr}}$ mV vs SCE	$b_c$ mV/decade	$b_a$ mV/decade	LPR ohmcm <sup>2</sup>	$I_{\text{corr}}$ A/cm <sup>2</sup>
AU	-0.422	129	337	$1.68 \times 10^6$	$2.40 \times 10^{-8}$
AU + 50 ppm NaCl	-0.463	142	297	$8.89 \times 10^5$	$4.70 \times 10^{-8}$
AU + 100 ppm NaCl	-0.460	143	284	$1.10 \times 10^6$	$3.77 \times 10^{-8}$

**Corrosion resistance of NiTi super elastic alloy in artificial urine in presence of sodium chloride**

Polarization study has been used to confirm the formation of protective film formed on the metal surface during corrosion inhibition process. The polarization curves of NiTi super elastic alloy immersed in AU in the absence and presence of sodium chloride are shown in Fig. 2. The corrosion parameters were calculated and are given in Table 2. It is observed from Table 2 that when 50 ppm of sodium chloride is added to AU, the LPR value increases from  $1.84 \times 10^7$  to  $1.93 \times 10^7$  ohmcm<sup>2</sup> and the corrosion current ( $I_{\text{corr}}$ ) decreases from  $1.84 \times 10^{-9}$  to  $1.95 \times 10^{-9}$  A/cm<sup>2</sup>. When 100 ppm of sodium chloride is added to AU, the LPR value further increases to  $2.29 \times 10^7$  ohmcm<sup>2</sup> and the corrosion current ( $I_{\text{corr}}$ ) decreases to  $1.73 \times 10^{-9}$  A/cm<sup>2</sup>. In general it is observed that the corrosion resistance of NiTi super elastic alloy in AU increases in the presence of sodium chloride. It is observed from the table that the corrosion potential shifts to cathodic side (more negative) in the presence of sodium chloride. Hence it is concluded that in presence of sodium chloride, the cathodic reaction is controlled predominantly.

**Table 2: Corrosion parameters of NiTi super elastic alloy immersed in AU in absence and presence of sodium chloride obtained by polarization study**

System	$E_{\text{corr}}$ mV vs SCE	$b_c$ mV/decade	$b_a$ mV/decade	LPR ohmcm <sup>2</sup>	$I_{\text{corr}}$ A/cm <sup>2</sup>
AU	-0.432	124	208	$1.84 \times 10^7$	$1.84 \times 10^{-9}$
AU + 50 ppm NaCl	-0.493	121	304	$1.93 \times 10^7$	$1.95 \times 10^{-9}$
AU + 100 ppm NaCl	-0.503	121	368	$2.29 \times 10^7$	$1.73 \times 10^{-9}$

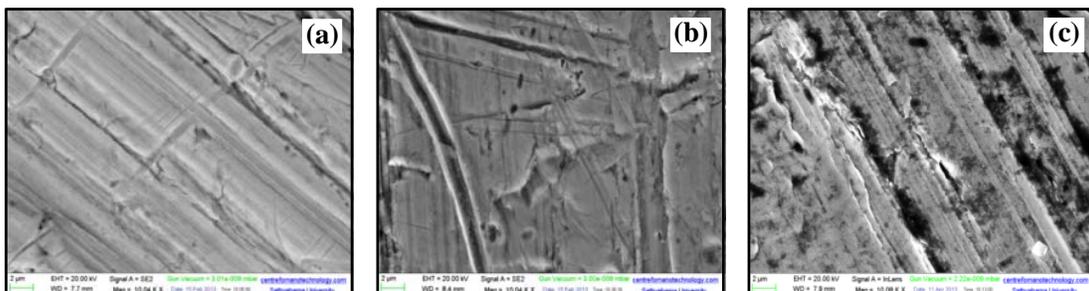


**Fig. 2: Polarization curves of NiTi Super elastic in various test solutions (a) AU (b) AU+ 50 ppm of sodium chloride (c) AU+ 100 ppm of sodium chloride**

### Scanning electron microscopy (SEM)

#### SEM Analysis of SS 316L surface

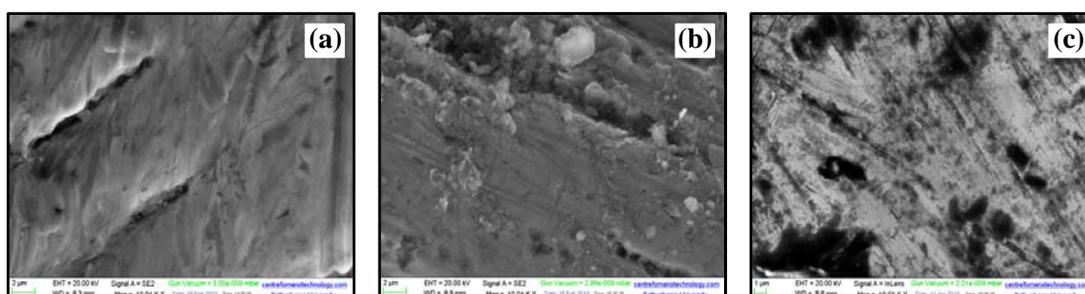
The SEM image of SS 316L specimen immersed in AU for 1 day in the absence and presence of sodium chloride system are shown in Fig. 3 (images (a, b, c)), respectively. The SEM micrographs of polished SS 316L surface in Fig. 3 (a) image shows the smooth surface of the metal. This shows the absence of any corrosion products on the metal surface. The SEM micrographs of SS 316L surface immersed in AU in Fig. 3 image (b) shows the roughness of the metal surface, which indicates the corrosion of SS 316L in AU. Fig. 3 image (c) indicates that in presence of 100 ppm sodium chloride in AU, the surface coverage increases, which in turn results in the formation of insoluble complex on the surface of the metal and the surface is covered by a thin layer of additives which control the dissolution of SS 316L. Such results have been reported earlier<sup>7</sup>.



**Fig. 3: (a) Polished SS 316L (control) – Magnification X10000 (b) SS 316L immersed in AU (c) SS 316L immersed in AU containing 100 ppm of sodium chloride**

### SEM Analysis of NiTi super elastic alloy surface

The SEM image of NiTi super elastic alloy specimen immersed in AU for 1 day in the absence and presence of sodium chloride system are shown in Fig. 4 (images (a, b,c)) respectively. The SEM micrographs of polished NiTi super elastic alloy surface in Fig. 4 (a) image shows the smooth surface of the metal. This shows the absence of any corrosion products formed on the metal surface. The SEM micrographs of NiTi super elastic alloy surface immersed in AU in Fig. 4 image (b) shows the roughness of the metal surface, which indicates the corrosion of NiTi super elastic alloy in AU. Fig. 4 image (c) indicates that in presence of 100 ppm sodium chloride in AU, the surface coverage increases which in turn results in the formation of insoluble complex on the surface of the metal and the surface is covered by a thin layer of additives, which control the dissolution of NiTi super elastic alloy.



**Fig. 6: (a) Polished NiTi super elastic alloy (control) – Magnification X10000  
(b) NiTi super elastic alloy immersed in AU (c) NiTi super elastic alloy immersed in AU containing 100 ppm of sodium chloride**

### CONCLUSION

The present study leads to the following conclusions: Polarization study reveals that NiTi super elastic alloy is more corrosion resistance than SS 316L. The SEM micrographs confirm the formation of protective layer on the metal surface.

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