

## Comparative Study on Corrosion Inhibition of Metals and Alloys in Artificial Urine (Synthetic Urine) in Presence of Urea



### Chemistry

**KEYWORDS :** Mild steel (MS), SS 316L, Nickel Titanium super elastic alloy, artificial urine, urea.

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### ABSTRACT

*Corrosion resistance of three metals namely mild steel (MS), SS 316L, Nickel Titanium super elastic alloy has been evaluated in artificial urine in the absence and presence of urea. Potentiodynamic polarization study has been used to investigate the corrosion behavior of these metals. The order of corrosion resistance of metals in artificial urine, in the absence and also in the presence of urea was discussed.*

### I. INTRODUCTION

Metallic biomaterials are commonly used in reconstruction in the orthopedic and dental surgery, operative cardiology and urology. Implant alloys exhibit attractive properties such as mechanical strength and biocompatibility, corrosion resistance, safety, ductility, and wear resistance. Stainless steels, titanium alloys and cobalt alloys are commonly used as biomaterials. [1] - [7] Biocompatibility of implants in tissue environment is determined by inseparable biochemical, biomechanical and bio-electronic factors. Biological reactions are analyzed with respect to metabolic, bacteriological, immunological and oncological processes [8], [10]-[13], [15]-[17], [19] - [25], [28]. Current chemical compositions of the stainless steel (Cr-Ni-Mo) should ensure good pitting corrosion resistance and monophasic austenitic structure. The austenite grain size (less than 4 acc. to ISO) and non-metallic inclusions (max. 1.5 acc. to ISO) are limited. Fine grain and low level of non-metallic inclusions ensure good mechanical properties and reduce crackability, specially in implants with small cross-sections. They also increase corrosion resistance of implants [16], [17], [23]. Great number of publications is focused on generalization of corrosion failure of implants. These analyses are focused on implants commonly used in reconstruction in the orthopedic, dental surgery, operative cardiology and urology. These implants are mainly made of austenitic stainless steel [8], [9], [12], [14], [18], [26] - [28]. Long-term research on corrosion of implants made of the mentioned steel show the complexity of corrosion processes depending on the implant form, its chemical and phase composition, surface condition, surgical procedure and implantation period [16], [17], [23]. Corrosion products infiltrate tissues. This process is called metallosis [10]. Phatomorphological changes, dependent on the type and concentration of elements, occur in tissues close to implant. Histopathological changes are observed in the detoxication organs (liver, kidneys, spleen) [16]. Therefore, corrosion tests in simulated body fluids are the basis for searching optimal fields of usage and improvement of existing solutions. In general the human urine contains urea and also excreted by the human body. In this research paper, if the person undergone implantation in the urinary tract how the metal undergoes corrosion in the presence of excess amount of urea. The present work was undertaken to study the corrosion behavior of three metals namely mild steel (MS), Nickel Titanium super elastic alloy and SS 316L in artificial urine, in the absence and presence of 50ppm and 100ppm of urea by Potentiodynamic polarization study. Corrosion parameters such as corrosion potential, corrosion current and linear polarization resistance value have been derived from these studies.

### II. EXPERIMENTAL

#### A. Materials and Methods

Three metals namely mild steel (MS), SS 316L, Nickel Titanium super elastic alloy were chosen for the present. The composition of mild steel was (wt %): 0.026S, 0.06P, 0.4 Mn, 0.1 C and balance iron (ArockiaSelvi et.al. 2009) [29]. The composition of SS 316 L was 18% Cr, 12% Ni, 2.5% Mo, <0.03% C and the balance iron [30]. The composition of Ni-Ti super elastic alloy was (wt %) Ni 55.5, and balance Ti [31]. 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) (J. Przondziona et al. 2009) [32], whose composition was: Solution A: CaCl<sub>2</sub>·H<sub>2</sub>O - 1.765g/l, Na<sub>2</sub>SO<sub>4</sub> - 4.862g/l, MgSO<sub>4</sub>·7H<sub>2</sub>O - 1.462g/l, NH<sub>4</sub>Cl - 4.643g/l, KCl - 12.130g/l. Solution B: NaH<sub>2</sub>PO<sub>4</sub>·2H<sub>2</sub>O - 2.660g/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 (W.Kajzer et al, 2006) [5].

In electrochemical studies the metal specimens were used as working electrodes. Artificial urine (AU) was used as the electrolyte (10 ml). The temperature was maintained at 37±0.1°C. Commercially available urea was used in this study. 50ppm and 100ppm of urea was used in artificial urine.

#### B. Potentiodynamic Polarization

Polarization studies were carried out in a CHI- Electrochemical workstation with impedance, Model 660A. A three electrode cell assembly was used. The working electrode was one of the three metals. A saturated calomel electrode (SCE) was the reference electrode and platinum was the counter electrode. From the polarization study, corrosion parameter such as corrosion potential ( $E_{corr}$ ), Corrosion current ( $I_{corr}$ ) and Tafel slopes (anodic =  $b_a$  and cathodic =  $b_c$ ) were calculated.

### III. RESULTS AND DISCUSSION

#### Polarization Study:

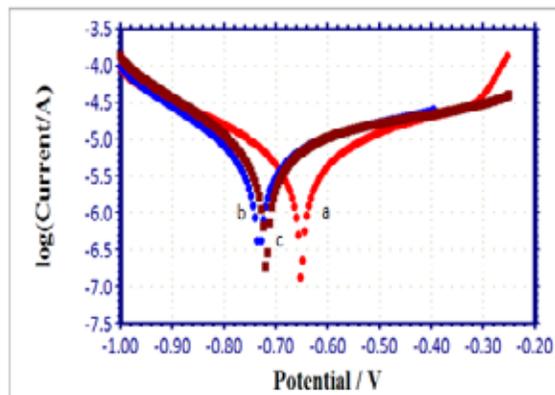
##### 1. Corrosion Resistance of Mild Steel in AU in Presence of Urea:

It is known to everyone that MS undergoes corrosion rapidly in AU. Hence it should not be used as implant material in body fluids. However in the presence study, the corrosion resistance of MS is chosen just compare the corrosion resistance of other metals with the corrosion resistance of MS. The polarization curves of mild steel immersed in AU in the absence and presence of urea are shown in Fig.1. The corrosion parameters namely LPR,  $I_{corr}$ ,  $E_{corr}$ , Tafel slopes ( $b_c$ = cathodic,  $b_a$ = anodic) are given in Table.1

**TABLE.1**  
Corrosion Parameters of MS Immersed in AU in Absence and Presence of Urea Obtained by Polarization Study.

System	E <sub>corr</sub> mv vs SCE	b <sub>c</sub> mv/decade	b <sub>a</sub> mv/decade	LPR ohmcm <sup>2</sup>	I <sub>corr</sub> A/cm <sup>2</sup>
AU	-0.651	183	208	11415	3.69x10 <sup>-6</sup>
AU+50ppm urea	-0.732	162	239	9777	4.29 x10 <sup>-6</sup>
AU+100ppm urea	-0.719	160	245	8688	4.85 x10 <sup>-6</sup>

It is observed from Table.1 that when 50ppm of urea is added to AU, the LPR value decreases from 11415 to 9777 ohmcm<sup>2</sup>. Correspondingly the corrosion current (I<sub>corr</sub>) increases from 3.69 x 10<sup>-6</sup> to 4.29 x 10<sup>-6</sup>A/cm<sup>2</sup>.When 100ppm of urea is added to AU, the LPR value further decreases to 8688 ohmcm<sup>2</sup> and the corrosion current (I<sub>corr</sub>) increases to 4.85 x 10<sup>-6</sup>A/cm<sup>2</sup>.In general it is observed that the corrosion resistance of MS in AU decreases in the presence of urea[32] - [35]. It is observed from the table that the corrosion potential shifts to anodic side (less negative) in the presence of urea. Thus, polarization study confirms the formation of a corrosive film on the metal surface.



**Fig.1. Polarization curves of MS in various test solutions.**  
a) AU b) AU+ 50ppm of urea c) AU+ 100ppm of urea

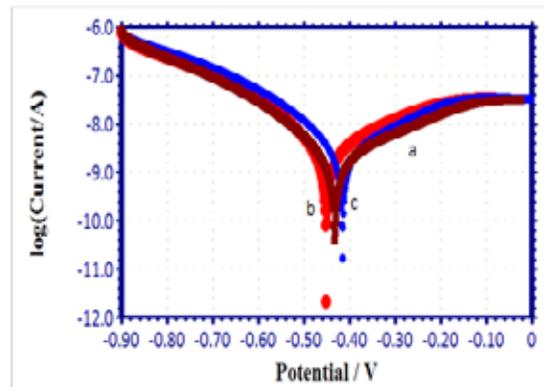
**2. Corrosion Resistance of Ni-Ti Superelastic in AU in Presence of Urea:** The polarization curves of Ni-Ti superelastic alloy immersed in AU in the absence and presence of urea are shown in Fig.2. The corrosion parameters namely LPR, I<sub>corr</sub>, E<sub>corr</sub>, Tafel slopes (b<sub>c</sub> = cathodic, b<sub>a</sub> = anodic) are given in Table.2

**TABLE.2**  
Corrosion Parameters of Ni-Ti Superelastic Alloy Immersed in AU in Absence and Presence of Urea Obtained by Polarization Study.

System	E <sub>corr</sub> mv vs SCE	b <sub>c</sub> mv/decade	b <sub>a</sub> mv/decade	LPR ohmcm <sup>2</sup>	I <sub>corr</sub> A/cm <sup>2</sup>
AU	-0.432	124	208	1.84x10 <sup>7</sup>	1.84x10 <sup>-9</sup>
AU+50ppm urea	-0.451	126	195	1.21x10 <sup>7</sup>	2.76x10 <sup>-9</sup>
AU+100ppm urea	-0.415	127	190	1.17x10 <sup>7</sup>	2.82x10 <sup>-9</sup>

It is observed from Table.2 that when 50ppm of urea is added to

AU, the LPR value decreases from 1.84 x 10<sup>7</sup> to 1.20 x 10<sup>7</sup>ohmcm<sup>2</sup>. Correspondingly the corrosion current (I<sub>corr</sub>) increases from 1.84 x 10<sup>-9</sup> to 2.76 x 10<sup>-9</sup>A/cm<sup>2</sup>.When 100ppm of urea is added to AU, the LPR value further decreases to 1.17 x 10<sup>7</sup> ohmcm<sup>2</sup> and the corrosion current (I<sub>corr</sub>) increases to 2.82 x 10<sup>-9</sup> A/cm<sup>2</sup>. In general it is observed that the corrosion resistance of Ni-Ti super elastic alloy in AU decreases in the presence of urea. It is observed from the table that the corrosion potential shifts to anodic side (less negative) in the presence of urea. Hence it is concluded that in presence of urea, it forms a corrosive film on the Ni-Ti super elastic alloy surface. [33] - [36]



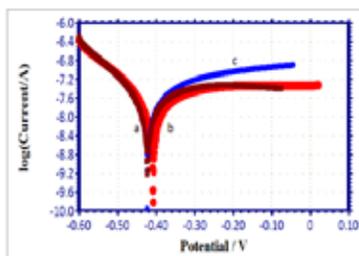
**Fig.2. Polarization curves of Ni-Ti Super elastic in various test solution**  
a) AU b) AU+ 50ppm of urea c) AU+ 100ppm of urea

**3. Corrosion Resistance of SS 316L in AU in Presence of Urea:** The polarization curves of SS 316L immersed in AU in the absence and presence of urea are shown in Fig.3. The corrosion parameters namely LPR, I<sub>corr</sub>, E<sub>corr</sub>, Tafel slopes (b<sub>c</sub> = cathodic, b<sub>a</sub> = anodic) are given in Table.3

**TABLE.3**  
Corrosion Parameters of SS 316L Immersed in AU in Absence and Presence of Urea Obtained by Polarization Study.

System	E <sub>corr</sub> mv vs SCE	b <sub>c</sub> mv/decade	b <sub>a</sub> mv/decade	LPR ohmcm <sup>2</sup>	I <sub>corr</sub> A/cm <sup>2</sup>
AU	-0.422	129	337	1.68x10 <sup>6</sup>	2.40x10 <sup>-8</sup>
AU+50ppm urea	-0.407	136	336	1.89x10 <sup>6</sup>	2.22x10 <sup>-8</sup>
AU+100ppm urea	-0.423	134	251	1.44x10 <sup>6</sup>	2.63x10 <sup>-8</sup>

It is observed from Table.3 that when 50ppm of urea is added to AU, the LPR value increases from 1.68 x 10<sup>6</sup> to 1.89 x 10<sup>6</sup> ohmcm<sup>2</sup>. Correspondingly the corrosion current (I<sub>corr</sub>) decreases from 2.40 x 10<sup>-8</sup> to 2.22 x 10<sup>-8</sup>A/cm<sup>2</sup>.When 100ppm of urea is added to AU, the LPR value decreases from 1.89x10<sup>6</sup> to 1.44 x 10<sup>6</sup> ohmcm<sup>2</sup> and the corrosion current (I<sub>corr</sub>) increases to 2.63 x 10<sup>-8</sup>A/cm<sup>2</sup>.In general it is observed that the corrosion resistance of SS 316L in AU increases in the presence of 50ppm of urea but it was decreased in the presence of 100ppm of urea. It is observed from the table that the corrosion potential shifts to cathodic side (more negative) in the presence of 50ppm of urea. Hence it is concluded that in presence of 50ppm of urea, it forms a protective film on the metal surface but in 100ppm of urea a protective film is formed on the metal surface but it is not stable. It was easily broken by chloride and sulphate ions present in urine.



**Fig.3. Polarization curves of SS 316L in various test solutions.**

a) AU b) AU+ 50ppm of urea c) AU+ 100ppm of urea

#### IV.CONCLUSION

The corrosion behavior of three metals namely mild steel (MS), SS 316L, Nickel Titanium super elastic alloy have been studied in artificial urine in the absence and presence of urea. Polarization has led to the following conclusions.

In the absence of urea, the order of corrosion resistance was:

Ni-Ti super elastic >SS 316L>Mild steel

In the presence of 50ppm urea, the order of the corrosion resistance was

SS 316L >Ni-Ti super elastic >Mild steel

In the presence of 100ppm urea, the order of the corrosion resistance was

SS 316L >Ni-Ti super elastic >Mild steel

Ni-Ti super elastic was more corrosion resistant in the absence of urea than in its presence.

SS 316L was more corrosion resistant in the presence of urea than in its absence.

Mild steel was less corrosion resistant in the presence of urea than in its absence.

From the above data, SS 316L is best suited for implantation.

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