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Electrochemical behavior of various implantation biomaterials in the presence of various simulated body fluids–an overview

ABSTRACT

In Modern medicine, metals and alloys are being used as implants. The Corrosion behaviour of various biomaterials under artificial body fluids are being studied. Artificial biomaterials are being implanted inside the human body to replace bone, teeth, etc. Even organs are being medically substituted with different types of metals such as mild steel, carbon steel, Ni-Cr alloy, Fe-Cr alloy, 22 carat Gold,24 carat Gold Tin, etc. due to their biocompatibility. This is achieved by connecting these metals directly with body tissues. The metals tend to corrode when it gets in contact with human body fluids. The body fluids thereby come in direct contact with tissues and the tissues are in contact with the metal thus causing the metal to corrode. And hence the corrosion resistance studies such as polarisation, AC impedance, cyclic voltammetric studies, etc, are being conducted in a medium like artificial blood plasma, artificial urine, artificial salvia, artificial sweat, Hank solution, Ringer solution, etc. The different body fluids are examined in the presence of different implantation metals by electrochemical methods and protective films are formed which are analyzed by various surface analysis techniques such as AFM, FTIR-UV, SEM, etc. The research findings will thereby be very helpful to the medical field.

Keywords: *Corrosion, Hank solution, Alloy, Artificial body fluids.*

1. INTRODUCTION

Metallic biomaterials are often employed in orthopedic and dental surgery, operative cardiology, and urological repair. Mechanical strength and biocompatibility, corrosion resistance, safety, ductility, and wear resistance are all desirable qualities in implant alloys[1-39]. Biomaterials such as mild steel, carbon steel, Ni-Cr alloys, 22 carat Gold, 24 carat Gold, tin, etc, are being used in the human body for various medical purposes. These metals when comes in contact with the body fluids such as blood plasma, sweat, Hank solution, etc, may tend to corrode. So the corrosion resistance of these metals in artificial body fluids is being studied in the presence and absence of inhibitors (additives) and results are being concluded with the Corrosion Resistance factors. Methods like SEM, TEM, AFM are commonly used to examine metals after their corrosion process. The detailed overview of various biomaterials and their recorded results are being summarised below [1-39].

Advance medical science uses metals and alloys as implants in human body. These metals may tend to corrode with time when they interact with body fluids. Thus the corrosion resistance of these metals are being studied in artificial body medium using various inhibitors (additives) and the corrosion resistance of these metals and alloys with suitable inhibitor is concluded.

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Table 1. The corrosion behavior of various metal and its alloys

Tabela 1. Korozijsko ponašanje različitih metala i njegovih legura

S. No	METAL	MEDIUM	Additive	METHOD	FINDINGS(Reference)
1.	Mild Steel Galvanised Steel SS 316L	Artificial Sweat	-	Potentiodynamic Polarization	Corrosion Resistance : GS > SS 316 > MS Material Resistance : SS 316 > MS > GS Compactness of the film: SS316 > MS > GS[1]
2	Mild steel Ni-Ti super elastic alloy	Artificial Urine	Urea	Potentiondynamic polarisation Surface examination Study Scanning Electron Microscopic Studies	Ni-Ti has more Corrosion resistance in absence of urea than in presence Mild steel has less corrosion resistance in presence of urea than in absence[2]
3	Ni-Ti alloy Thermoactive alloy SS 316L	Artificial saliva	Coffee	Potentiodynamic Polarisation study AC Impedance spectra	Corrosion Resistance of alloys: SS 316L >Thermoactive alloy > Ni-Ti alloy[3]
4	Mild steel Mild steel coated with Zn SS 316L	Artificial saliva	D-Glucose	Potentiodynamic Polarisation AC impendancespectra	Corrosion Resistance the absence and presence of D-Glucose SS 316L > MS-Zn > MS[4]
5	$Zr_{65}Cu_{17.5}Ni_{10}Al_{7.5}$ $(Zr_{60}Nb_5)Cu_{17.5}Ni_{10}Al_{7.5}$ $(Zr_{60}Nb_5)Cu_{17.5}(Ni_5Pd_5Al_{7.5}$	Artificial Saliva Phosphate buffered solution Artificial Blood plasma	-	Electrochemical polarisation Galvanostatic-step measurement	Addition of Nb enhanced the corrosion resistance among the Zr- based Bulk Metallic Glasses (BGM)[5]
6	Copper	Artificial Blood Plasma	Adenine and 2,6-diaminopurine potassium sorbate	Potentiodynamic polarisation Electrochemical Impedance spectroscopy Cyclic voltammetry measurements	Efficiency up till 90% was provided with both compounds[6]
7	AISI 420 Custom 630 Custom 455	Artificial Blood Plasma	-	Potentiodynamic polarisation Electrochemical Impedance analysis Magnetic behaviour	Custom 630 was the better corrosion resistive material [7]
8	La added 316L stainless steel	Simulated Blood plasma Hank's solution	-	Potentiodynamic polarisation	Corrosion Resistance of La added 316L stainless steel in both solution is improved due to the effect of La in the purification of steel[8]
9	Zr-Ti Zr-Hf	Hank's Solution	-	Potentiodynamic polarisation Homogenization Heattreatment	Addition of Ti to Zr over 5% increases pitting corrosion resistance. Addition of Hf to Zrdecreased the corrosion resistance[9]

10	Ti5Al4V Ti6al4V	Ringer solution Phosphate Buffer solution	H_2O_2	Potentiodynamic polarisation Heat treatment fabrication method	The alloy was found to have better corrosion resistance in test solutions[10]
11	Co-Cr Ni-Cr Cu-Ni-Al Commercially pure Ti (cpTi)	Artificial Saliva	-	Electrochemical impedance spectroscopy Tafel& cyclic polarisation.	Corrosion Rates Cu-Ni-Al>cpTi> Co-Cr> Ni-Cr> Co-Cr[11]
12	SS 316L	Artificial Blood Plasma	Amoxicillin	Potentiodynamic Polarization Electrochemical impedance Method	Corrosion Resistance of SS 316L in ABp is of the order: SS316 + ABp + 10ppm Amoxicillin > SS316 + 50ppm + ABp> SS 316 L + ABp[12]
13	Mild Steel Mild Steel coated with Zinc SS 316L	Artificial saliva	Spirulina	Potentiodynamic Polarization Electrochemical impedance Method	SS 316L and MS-Zn has more Corrosion resistance in the absence of Spirulina than in their presence MS has more Corrosion Resistance in the presence of spirulina than in their absence[13]
14	Ni-Cr Alloy	Artificial Saliva	Metformin Hydrochloride (250 mg)	Potentiodynamic Polarization AC Impedance Method	In the presence of Metformin Hydrochloride the corrosion resistance of NiCr alloy increases.[14]
15	Fe-17Cr-8Ni alloy Fe-7Cr-10Ni alloy Fe-17 Cr-14Ni alloy	Stimulated body fluid	H_2O_2 and albumin	Potentiodynamic Polarization Electrochemical impedance Method	Fe-Cr-14Ni alloy contains smallest rate of corrosion than Fe-17Cr-8Ni and Fe-17Cr-10Ni alloys. Fe-17Cr-14Ni obtained the smallest corrosion rate due to the protective oxide film Fe-17Cr-8 Ni < Fe-7 Cr-10Ni < Fe-17 Cr-14Ni[15]
16	Mild steel Ni-Ti super elastic alloy	Artificial Urine	NaCl	Potentiodynamic Polarisation study	Ni-Ti has more Corrosion resistance in presence of NaCl than in absence Mild steel has less corrosion resistance in presence of NaCl than in absence.[16]
17	Mild steel 22-carat gold 18-carat gold Ni-Cr alloy SS316L	Ringer's solution	-	Electrochemical impedance Method	Corrosion Resistance : Ni-Cr> Gold 22> SS 316L > Gold 18 > mild steel[17]
18	Austenitic stainless steel Cr-Ni-Mo	Artificial Urine Tyrode's physiological solution Artificial plasma	-	Potentiodynamic Polarization	Cr-Ni-Mo steel shows better corrosion resistance in Tyrode's physiological solution[18]

19	Ti-6Al-4V Alloy with Nitride coating	Tyrode's solution 0.9% NaCl	-	Chemical – Thermal Treatment X-ray phase analysis SEM Electro Chemical Test	Ti-6Al-4V alloy has higher corrosion resistance in Tyrode's solution [19]
20	Austanitic 304 Stainless Steel	Tyrode's physiological solution	-	Potentiodynamic Polarization AC Impedance Method SEM	It was seen that electro polishing increases the uniform pitting corrosion in The Austanitic 304 Stainless Steel[20]
21	Ni-Ti Ni-TI-Cu Pure Ti Ti-6-Al-4V 316L	Hank's solution	-	Potentiometric polarization Method Re Passivation Test	The susceptibility to corrosion of the order : cpTi≈Ti6Al4V<<316L <NiTiCu<NiTi Cp Ti and Ti6Al4V are resistant to the initiation of crevice corrosion in Hank'ssolution Cu addition to NiTi improves the repassivation capability by EDS analysis[21]
22	Co-Cr-W-Ni alloy	Artificial blood plasma Artificial urine Tyrode solution	-	Electrochemical impedance Method	Co-Cr-W-Ni showed good corrosion resistance[22]
23	Ti Co-Cr Alloy	Artificial saliva	-	Electrochemical impedance Method	Titanium was found to have high Corrosion Resistance [23]
24	AZ91D Ti-6Al-4V	Stimulated blood fluids at 37°C	-	Potentiometric polarization Method Electrochemical impedance Method	The corrosion resistance of Titanium alloy was high compared to Magnesium alloy[24]
25	Co-Cr Ni-Cr alloy	Artificial saliva	Streptococcus mutans	Potentiondynamic Polarisation Impedance spectroscopy Open circuit potential measurement	The presence of Streptococcus mutans reduced corrosion rate of both alloys. [25]
26	Mild steel Ni-Cr SS-316 Cu-Ni-Ti 22-carat gold 24-carat gold Super elastic Ni-Ti	Artificial Plasma	Glucose	Tafel electrochemical impedance spectroscopic experiments	Ni-Cr and SS_316 showed good corrosion resistance both in the absence and in the presence of 0.05g of glucose The rest 5 metals showed good corrosion resistance in small amounts of glucose. [26]
27	Ni-Ti based alloys (Super Elastics)	Artificial Saliva	Sulfa drugs like Phexin	Polarisation study	0.1g of phexin has more corrosion resistance than 0.05g of phexin when added. [27]

28	Ni-Ti based alloys (Super Elastics)	Synthetic Urine	Glucose	SEM with EDAX and AFM	The corrosion resistance decreased at low concentrations and increased at higher concentrations. [28]
29	Cu-Ni-Ti	Artificial Blood Plasma	Cholesterol	Potentiodynamic polarisation AC Impendance system	Maximum Corrosion resistance was observed in 100ppm of Cholesterol than with 50ppm and in absence of Cholesterol[29]
30	Ti-Ni SMA Co-Cr alloy	Tyrode's solution	-	3-electrode system Potentiostat/ Galvanostat	Pitting corrosion of Ti-Ni alloy was greater than Co-Cr alloy[30]

2. CONCLUSION

The artificial biomaterials implanted inside the human body in the place of bone, teeth, and even organs are being medically substituted with different types of metals such as mild steel, carbon steel, Ni-Cr alloy, Fe-Cr alloy, 22 carat Gold, 24 carat Gold, Tin, etc. and the studies were summarized. Corrosion resistance studies such as polarisation, AC impedance, cyclic voltammetric studies conducted in mediums like artificial blood plasma, artificial urine, artificial salvia, artificial sweat, Hank solution, Ringer solution, etc. were determined. Future Research on the field of Corrosion Resistance of various biomaterials can be analysed and studied for the betterment of implantation in the field of medicine.

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IZVOD

ELEKTROHEMIJSKO PONAŠANJE RAZLIČITIH METALA ZA IMPLANTACIJU U PRISUSTVU RAZLIČITIH SIMULIRANIH TELESNIH TEČNOSTI – PREGLED

U savremenoj medicini metali i legure se koriste kao implantati. Proučava se ponašanje korozije različitih biomaterijala u veštačkim telesnim tečnostima. U ljudsko telo se ugrađuju veštački biomaterijali koji zamenjuju kosti, zube itd. Čak se i organi medicinski zamjenjuju različitim vrstama metala, poput mekog čelika, ugljeničnog čelika, legure Ni-Cr, legure Fe-Cr, 22-karatnog zlata, 24-karatnog zlatnog kalaja itd., zbog njihove biokompatibilnosti. To se postiže povezivanjem ovih metala direktno sa tkivima tela. Metali imaju tendenciju korozije kada dođu u kontakt sa tečnostima ljudskog tela. Telesne tečnosti na taj način dolaze u direktan kontakt sa tkivima, a tkiva su u kontaktu sa metalom i na taj način izazivaju koroziju metala. Stoga se studije otpornosti na koroziju, poput polarizacije, impedanse naizmenične struje, cikličnih voltametrijskih studija itd., sprovode u medijumu poput veštačke krvne plazme, veštačkog urina, veštačke salvije, veštačkog znoja, Henkovog rastvora, Ringerovog rastvora itd. Tečnosti se ispituju u prisustvu različitih implantacionih metala elektrohemijskim metodama i formiraju se zaštitni filmovi koji se analiziraju različitim tehnikama površinske analize kao što su AFM, FTIR-UV, SEM itd. Nalazi istraživanja će time biti od velike pomoći medicinskom polju.

Ključne reči: *Korozija, Henkov rastvor, legura, veštačke telesne tečnosti.*

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