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Review paper
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Corrosion behaviour of metals in artificial body fluid an over view

The Corrosion Performances in Various artificial body fluids of various metals are evaluated, Artificial human blood, urine serum, Joint fluid, simulated bile solutions, artificial salaiva, Hank's solutions Ringers, Tyrode of the solution, Cigada solutions are examined with different type of metals such as Ni-Al-Fe alloys, TiO_2 nano tubes, cobalt alloys, Cr alloys, 316 stainless steel, Mg - alloys etc . There are used as implant materials for surgery. The Corrosion resistance tests were carried out in selected body fluids. To replace the bone, several metal and it alloys have been used as implantation metal. The Artificial body fluids are important to maintain our body health. Because the artificial body fluids directly connecting with tissues, Tissues are directly contact with implantation metals. The different or various body fluids are examined in presence of different or various implantation metals by electro chemical method. Protective films are formed. The films have been Analyzed by many surface Analysis techniques such as AFM, FTIR UV fluorescence spectra and SEM.

Key words: *corrosion, alloys, artificial human blood, urine, serum*

INTRODUCTION

Uses of some metal alloys such as cobalt alloys, Ni alloys, titanium alloys stainless steel are as implants, because of their biocompatibility. Hence there are used for reconstructive bone and teeth. The corrosion performances in various artificial body fluids of various metals are evaluated, artificial human blood, urine serum, Joint fluid, simulated bile solutions, artificial salaiva, Hank's solutions Ringers, Tyrode of the solution, Cigada solutions are examined with different type of metals. The Artificial body fluids are important to maintain our body health. Because the artificial body fluids directly connecting with tissues, Tissues are directly contact with implantation metals. The different or various body fluids are examined in presence of different or various implantation metals by electro chemical method.

RESULT AND DISCUSSION

Metals:

In artificial body fluids some alloy materials have been used to control the corrosion of various of metals, such as Mg [1-10, 16,13,30,33], Cobalt alloys [8,10,12,13], stainless steel [6,25,54,], mild steel, titanium and its alloys [35], aluminum and its alloys, cupper and super elastic.

Medium:

The corrosion behavior of metals in various environments have been investigated in artificial blood, artificial urine, Tyrode's Ringer solutions, joint fluid have been used to study about the corrosion resistance.

Additives:

Various body fluids are used as mediums, alone or in combination with other such as, Glucose, Chloride or fluoride ions.

Temperature:

The Correction Resistance, of artificial body fluids have been evaluated at room temperature and also at high temperature

Methods:

Various methods have been used to evaluate the corrosion resistance of various metals under various artificial body fluid medium, usually [25, 12, 11, 16, 18, 22] weight loss method, electro [25, 12, 11, 16, 18, 22] chemical studies and SEM studies have been employed.

Surface Analysis:

The protective films formed on metal surface, during the process of corrosion protection of metals by artificial body fluids have been analysed by various surface Analysis techniques such as SEM [43], Raman Spectrographs Tafel [23] Electro-chemical impedances spectroscopy experiments and potentiodynamic techniques [22,42]. In general it has been observed that the protective film consists of the metal active principle complex.

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Cobalt alloys:

Cobalt alloys are one of the main groups of metallic materials used as implants. They are numbered among biomaterials of good biocompatibility. Their mechanical properties and corrosion resistance are determined by chemical composition and the technology of production as well.

The homogeneous structure obtained in heat treatment and plastic working process, is crucial for corrosion resistance. It is also influence diverse properties used in implants applied in traumatologes, Urology or cardiology. In recent years the incase of bio compatibility is realized by formation of surface layers. It is connected with biological activity of implanted metals and their corrosion.

In cobalt base alloys the main element present in corrosion products is undoubtedly cobalt. Its toxicity is small even if the concentration is 1000 higher than normal. Cobalt ions are mainly accumulated in spleen, In tissues contacting directly with the implant the combat concentration is 300 = 6000 higher. Higher concentration if cobalt can be observed in hair, blood and urine,

Stainless steel:

316 L Stainless steel is used as biomedical due to its excellent mechanical properties and corrosion resistance. However this alloys contains chromium liable to do serious harm to human bodies so actual use will require prevention of divert contact with biological tissue.

Biocompatibility of implants in tissue environment is determined by inseparable biochemical, biomechanical and bio electronic factors, Biological reactions are analysed with respect to metabolic, bacteriological, immutholgical and oncological processes.

Current chemical compositions, of the stainless steel (Cr-Ni-Mo) Should ensure good pitting corrosion resistance and monophase austenitic structure. 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.

The influence of different artificial body fluids on metallic corrosion was investigated by measurement of polarization curves and electro chemical impedance spectroscopy.

Titanium and its alloys:

Titanium and its alloys are widely used in dentistry as prosthetic appliances because of a high corrosion resistance and good biocompatibility. These valuable properties are caused by passive films that are rapidly formed in the body fluid environment. Recently mouth rinces, tooth pastes and prophylactic agents containing fluoride are utilizing to prevent the dental caries. The surface reaction on titanium under the existence of fluoride is important to understand the corrosion and tarnish of titanium in oral environment. Recently the corrosion of titanium was suppressed in solutions containing fluoride and eugenol.

In dentistry metallic materials are used as implants in reconstructive oral surgery to replace a single teeth or an array of teeth or in the fabrication of dental prosthesis such as metal plates for complete and partial dentures.

Advantages and Limitations

Rate of corrosion are studied various metal and it alloys shows corrosion resistance or behavior metals under various artificial medium. To prevent the corrosion of metals we choose or select good non corrosive metal under the suitable medium.

A list of various metal and its alloys have been shown as corrosion behavior (Table 1).

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

S.No	Metal	Medium	Methods	Finding
1	TiO_2 coating on TC_4	Stimulated body fluid	Fretting experiments	Fretting corrosion increased
2	Ni-Al-Fe intermetallic alloy	Simulated human body fluid	1.potentiodynamic polarisation curves 2.electrochemical impedance spectroscopy 3.electrochemical noise measurements	Similar or higher resistance than conventional AISI,316L type stainless steel corrosion is decreased as “Al” content in alloy increased
3	Effect of boron on Ni-Ti alloy	Simulated body fluid	1.potentiodynamic polarisation curves 2.Electrochemical impedancespectroscopy	200-500 ppm boron decrease corrosion.but 1000 ppm, Boron increase corrosion

4	Mg alloy of AZ91D	SBF	Heat treatment	Rate of corrosion less than as cast and T4 micro.str
5	AISI type 316 stainless steel after electropla-ting in a magnetic field	1.Pure distilled water 2.Ringers body fluid 3.aq.NaCl sol	1.Open circuit potential 2.Polarisation curves	Comparison of the corrosion behaviour of stainless steel in the absence of magnetic field
6	Zindovudine methacrylic acid	Human serum	Liquid chromatography and mass spectroscopy	Specificity of the molecularly imprinted polymer was evaluated
7	Implant cobalt alloy	Blood and Urine	Scratch and pin-on-disc wear tests	Synthesis and characterization of modified cobalts alloys
8	Ti-6AL-4V implant alloy	1.Urine 2.Serum 3.Joint fluid	1.Potentiodynamic method, 2.Cyclic votammetry, 3.Electrochemical impedance Spectroscopy.	Characteristic of a capacitive behaviour
9	Cr(iii) alloy or Co-Cr alloy	Serum proteins	Proteomic approach	Cr(iii) complexes were more easily engulfed by U937 macrophage like cells
10.	Nitinol mechanically polished nitinol and Electro polished nitinol.	Simulated bile solutions	1.cyclic potentiodynamic polarisation 2.Electrochemical impedance spectroscopy, 3.Cyclic polarisation	Whether nitinol exhibited a difference in behaviour between the two bile soltions and comparision with phosphate buffered saline
11.	Co-Cr-Mo biomaterial	1.Arficial salaiva 2.Artificial Sala-iva with modified tempr (7 c - 47 c) ph (1.4-13.4) 3.Salaiva with fluoride (1500 ppm)	1.Potentiodynamic polarisation 2.Potentiostatic polarisation 3.Cyclic voltammetry	Behaviour of (Co-Cr-Mo) tempe-rature and pH influenced .But fluoride did not produce changes.
12.	Co-Cr-Mo alloy	Under simulated body conditions	1.PDP 2.PSP 3.CV 4.Rotating disc Eletrode 5.Electrochemical impedance Spec 6.X-ray PES	Electrochemical properties of the alloy and the relavant mechanisms in passive and transpassive, states were studied in detail
13.	Nitrogen ion implantation on SUS 316 L ,Co-Cr alloy ,Pure Ti,Ti-6Al-4V.	Hank's Simulated body fluid.	Electrochemical technology AES	1.Pure Ti and Ti-6AL-4V most strong to N-ion implantation 2.Corrosion resistance of the Co-Cr-alloy is better than that of SUS316L
14.	Mg-alloys – AZ91D and WE43	Simulated body fluid	Cyclic loading	Corrosion rate of the two experimental alloys increased under cyclic loading compared to that static immersion test
15.	Ni-Al-Fe alloys	Simulated human body solution	Potentiodynamic polarisation curves Electrochemical impedance spectroscopy , Electrochemical noise measurements	Simularor Higher corrosion resistance thatn AISI 316L corrosion resistance decreased as the Al content in the alloy increased

16.	TiO_2nanotubes	Simulated body fluid	An anodization method	Apatite layer glown on the nanotubes decreased yet subsequently increased with variation of nanotubular surface morphology and length
17.	TiO_2 nano particle coated bio implant Ti-6Al-4V	1.NaCl 2.Hank's solution 3.Cigada solution	Micro Raman spectroscopy Electrochemical techniques Scanning electron microscopy EDS.	TiO_2 nanoparticle coatings increased the Pre-existing oxide layer on the Ti-6Al-4V surface, sewing to improve the bio implant corrosion resistance.
18.	AZ31 mg-alloy with different grain sizes	1.SBF 2.Chloride Solution 3.PBS (phosphate Buffer solution)	1.Open circuit potential 2.Polarisation of curves 3.Transient Currents 4.ECIS 5.SEM 6.EDS	The best corrosion behaviour of the A231 alloy the first grain alloy associated with the highest transfer resistance value after long periods of immersion in PBS.
19.	TiO_2 nano particles coated Ti-6AL-4V	SBF 1.NaCl 2.Hank's solution 3.cigada solution	Fractional order signal processing techniques.ECN	Skewness ,Kurtosis and noise Resistance were calculated.
20.	TiO_2 nano particle coated Ti-6AL-4V	SBF 1.NaCl 2. Hank's solution 3.Cigada solution	Micro Raman spestroscopy ECT SEM EDS ECIS	TiO2 coating increased the thickness of the pre-exsisting oxide layer on the Ti-6AL-4V surface sewing to improve the bio implant corrosion resistance
21.	TZNT	Ringer's solution	Potentiodynamic technique	TZNT posesses better corrosion resistance when compared with Ti6Al4V Ti6All7Nb and TA2
22.	Mg Mg alloys with different "Al"	SBF	Tafel Electrochemical Impedance spectroscopic experiments	The micro structure and Al content in the a-mg (Al) matrix significantly affected the corrosion properties of the alloys in the m-smf with |^ Al content the corrosion resistances of the samples were improved.
23.	TC4 (Ti-6Al-4V)	0.9% NaCl SBF	Tesler,tribo electro chemical curves	Micro arc oxidation coating on 'TC4' treated for 20 mins showed a better corrosion resistance and frictional performance
24.	Mg-alloy	Hank's solution simulated blood plasma	1.electrochemical method 2.Weight loss method	High corrosion of the initial decrease in the 2-3 days after stable corrosion. High corrosion was observed in Hank's solution than SBP due to high Cl-,low Ca2+ and Po4^3-
25.	1.Porous titania 2.Tio_2 3.Films of Ca or PhO_4 on Ti	Calicum and Phosphate ions	1.EIS 2.Electron diffraction X-ray 3.EDX 4.SEM	The oxides flims formed potentiostatically on Ti in H_2O_2 containing H_2SO_4 are capable to absorb biologically compatible ions.
26.	Cr,Fe,Ni from the stainless steel 316	Hanks Solution with or without H_2O_2	SEM, EDXS, XPS	In the absence of H_2O_2, formation of surface layer consisting mainly of $Ca_3(PO_4)_2$ was observed.

27.	Titanium and Ti-6Al-4V alloy	Artificial saliva	Electrochemical impedance spectrascopy	The corrosion resistance of Ti-23Ta alloy which is reduced by increasing F concentration or decreasing pH is related to the resistance of the inner compact layer.
28.	Titanium	Artificial bio fluid containing H_2O_2	EIS, SEM	The corrosion resistance of titanium is strongly affected by the presences of H_2O_2 and when the peroxide is removed, the metal displays a short resistance increase.
29.	Cold-rolled Ti-13NB-13Zr alloy and Ti-6Al-4V ELI alloy	Ringer's solution	Potentiodynamic polarization method	Ti-6Al-4V ELI alloy possesses the best combination of both corrosion wear resistance. Its CR slightly higher than that of Cold-rolled Ti-13NB-13Zr alloy.
30	CP-Mg and ZM21Mg alloy	Ringer's solution	Electrochemical impedance spectrascopy	A ZM21Mg alloy is promising material for the development degradable implants.
31	Titanium	Human plasma and cognate fluids SBF, SBF with added ovalbumin	EIS and surface Raman Spectrascopy	some caution in extrapolating corrosion results obtained in simulated biological fluids to the actual behaviour in vivo
32	TI6A14V alloy	SPF	linear polarization resistance and potentiodynamic polarization	The characterization of the corrosion products in the tested samples indicated a preferential attack of the α phase compare respect to phase by pitting corrosion and microgalvanic corrosion
33.	AISI 316L stainless steel, Titanium and cobalt alloys	simulated body fluid	electrochemical impedance spectroscopy (EIS) and anodic polarization curves	This work presents a study of the superficial composition and the corrosion resistance of AISI 316L stainless steel and the influence of its main alloying elements when they are exposed to an acidic solution that simulates the change of pH that occurs when an infection develops.
34.	Diamond coated stainless steel and uncoated stainless steel	simulated body fluid	potentiodynamic polarization test	This study showed that increasing the thickness of the Si interlayer of film improved the corrosion resistance with reduction of spallations and cracks.
35.	316LVM stainless steel	sodium nitrate electrolyte	cyclic potentiodynamic polarization	The simple electrochemical passivation technique discussed in the paper can be efficiently used to form highly pitting resistant passive films on 316LVM-built medical implant devices of any geometry.
36.	metal-on-metal arthroprostheses, metal-on-UHMPWE	blood and urine	synthesis and characterization studies	The mechanical behavior of the modified materials was investigated by scratch and pin-on-disc wear tests. The metal ion release of the modified surfaces was measured by in vitro experiments after wear tests.

37.	Nitinol, 316L stainless steel and Pt	simulated body fluid	Electrochemical studies	These results highlight the importance of evaluating the corrosion resistance of Nitinol under realistic conditions (mechanical loads, wear and fatigue) in order to establish multifaceted mechanisms that might lead to accelerated dissolution and failure of implanted stents
38.	Silane-parylene coating stainless steel 316L	Hanks solution	microscopic observations and electrochemical measurements	the addition of H_2O_2, simulating the inflammatory response of human body environment causes a dramatic destruction of the protective coating. Analysis of the experimental data in terms of circuit models enables proposing a deterioration mechanism. OH radicals formed at the metal surface attack the polymer, thus the deterioration starts from the metal/polymer interface and progress towards the outward surface.
39.	X2CrNiMo 17-12-2 steel	diversified strain, artificial urine	Electrochemical passivation studies, potentiodynamic method, X-ray photoelectron spectroscopy	The tests were carried out in order to determine suitability of X2CrNiMo 17-12-2 steel with modified surface and diversified strain hardening for production of wire used in urology
40.	NiTi alloy	fetal bovine serum	open circuit potential (OCP), electrochemical impedance spectroscopy (EIS), scanning electron microscopy (SEM), X-ray photoelectron spectroscopy (XPS), and inductively coupled plasma mass spectrometry (ICP-MS)	XPS shows that the composition of the oxide film formed in FBS is similar to that formed in PBS and it is composed of mainly Ti oxides with a small amount of Ti hydroxide. Hydrated Ti is observed on the outermost surface of the NiTi alloy. The thickness of the oxide film on the NiTi alloy immersed in PBS is 17±3.0nm and that on the sample immersed in FBS is 10±3.2 nm. The results are consistent with those obtained by EIS. The presence of FBS can accelerate leaching of Ni ions and the mechanism is investigated and discussed

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IZVOD

KOROZIONO PONAŠANJE METALA U VEŠTAČKIM TELESNIM TEČNOSTIMA

Upotreba nekih metala i legura, Ni-Al-Fe legure, TiO_2 nano cevi, kobalt legure, nerđajući čelik, Mg legure itd., u različitim veštačkim telesnim tečnostima dovodi do određenog stepena korozije. Ovi materijali se koriste kao implantati pri različitim operacijama. Otpornost na koroziju navedenih materijala je ispitivana u različitim telesnim tečnostima. Da bi se zamenile kosti korišćeni su neki metali i legure. Ovi materijali su u direktnom kontaktu sa raznim telesnim tečnostima. U prisustvu ovih različitih tečnosti ispituju se ovi implantati elektrohemijskim metodama. Na površinama ovih implatata se formiraju zaštitni filmovi. Ispitivanje ovih zaštitnih filmova je vršeno mnogim tehnikama površinske analize: AFM, FTIR, UV fluorescentna spektroskopija i SEM.

Key words: *korozija, legure, veštačka ljudska krv, urin, serum*

Pregledni rad

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