

Mechanical and Corrosion Studies of Magnesium Based Biodegradable Medical Implants

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Abstract

The biodegradable materials had become significantly advanced since 30 years. The “Biodegradable Metal” itself defines the metals & alloys which safely corrode itself in-vivo. As magnesium its alloys shows great potential as a biodegradable metal, it is preferred to use among Mg based, Fe based, Zn based biomaterials. The present review focuses on in-vitro studies of mechanical and corrosion behavior of AM50 & AZ81 magnesium based alloys as a biodegradable implant.

Keywords: Biomedical implants, Mechanical, corrosion, Degradation, Mg Alloys.

Introduction

Yearly, disease and accidents causes millions of people suffer from bone fracture. However, although the current treatment using traditional nondegradable biocompatible materials. In the present, the biodegradable implants are being considered as the alternative for traditional implants. Biomaterials are mainly classified as polymers, ceramics, bone cements. But the mechanical implants prefer for their mechanical strength, toughness with nontoxicity and allergy free elements are composed [1]. Also the biodegradable provides the temporary support for the fracture and starts degrading with matting new tissue formation. The presence of scaffold can serve as substrate for seeded cells facilitate new tissue formation at site of injury. Incorporation of drug or bioactive molecule may also accelerate new tissue formation [1,2].

The designing of biodegradable implants consist following important factors firstly material should be degrade over definite period. Secondly, the material should possess sufficient mechanical strength to sustain and also the scaffold function of material as temporary support should allow space the newly generated tissue to replace the defect[3]. As the magnesium and its alloy shows preferable mechanical property and excellent compatibility with human bone are greatly used as biomaterial for the human body implants.

Mg and its alloys possess active chemical property and also it is liable to be corroded in physiological environment after implementation without causing any toxicity and side effects. Mg plays important role in metabolism of mineral substance of bone by boosting the formation of teeth and bone. Mg and its alloy are suitable to be used in the blood vessel intervention and orthopedic due to close elastic module with human bone. With help of process such as extrusion which provides three dimensional compressive stresses, Mg alloy with high modulus of elasticity is obtained [4,5].

After several studies, it comes to know that the corrosion behavior of Mg is greatly depends on the alloying element and their microstructure. The present work aims to compare the in vitro electro chemical degradation behavior of biocompatible magnesium alloy such as AZ81 and AM50 etc. alloy the corrosion behavior was studied through analysis of corrosion resistance variation with immersion time using Electrochemical Impedance Spectroscopy (EIS) test. Corrosion resistance of these treated samples in solution simulating the physiological environment will be evaluated by

EIS, using standard corrosion tests. The haemolysis rate is quite high, so it can be controlled by coating of various thicknesses of different biocompatible materials. Also, conducted H₂ evolution test & immersion test to check corrosion and H₂ evolution as per expectations. Prototype is also preparation is carried out.

Literature Reviews

S. Remenniket. al. developed the highly ductile Mg-Bi-Ca and Mg-Bi-Si alloys and it was observed that the alloys corroded without any clinically visible gas formation. M.H. Idriset. et. al. studied characteristics of as cast and forged biodegradable Mg-Ca binary alloy with different percentages of calcium which was added to magnesium during melting of the alloy

Y.K.Kim prepared Mg-35Zn-3Ca alloy as a new biodegradable material and the pulsed power is used in constant current mode of DC power kinds of anodization. Applying current under 200mA/cm², the oxide film was observed to be irregular and incomplete on surface irrespective of frequency. As a result of potential-dynamic, the corrosion current decreased and the corrosion voltage increased in the high current anodized group. The most appropriate oxide layer was obtained in Mg-35Zn-3Ca under a current density of 300 mA/cm² and a frequency of 50 Hz. It was observed that anodized Mg-35Zn-3Ca alloy has good biocompatibility in vitro by current and frequency variation.

HE Sheng Ying et. al. added nano β -Tricalcium phosphate particles into Mg-Zn-Zr alloy to improve its microstructure and properties. The grains were observed to be significantly refined and the tensile test indicates that the ultimate tensile strength and the elongation of composites were improved with the addition of β -TCP. The electrochemical tests showed that the corrosion resistance of the composite was strongly enhanced comparing with that of the alloy.

An area that has recently received the most attention in the bio-Mg field is the study of coatings or surface modification to slow the degradation rates of various Mg alloys. In the case of Mg coatings they cannot be perfect barriers to corrosion (which would be the goal of coating system on a structural material).

Sanket Vathare et. al prepared samples of AZ31, AZ80 and AZ 91 for tensile and corrosion testing. They conducted various tests like wet analysis testing, mechanical testing and EIS testing in simulated body fluid to check suitable biocompatible material. They found that AZ91 has excellent corrosion resistance for implant purpose.

TAN Li-li et. al applied Ca-P coating on AZ31. They compared corrosion rate of Ca-P applied coating they found that Ca-P coated AZ31 have good corrosion resistance. They conducted hemolysis test for checking biocompatibility they found that Ca-P coated have good biocompatibility.

Sridevi Brundavanam et. al studied electrochemical corrosion of magnesium metals and alloys suggested and

different preventive measures of coating, anodisation. Zhen Zhen et. al stated different corrosion testing methods like immersion test, dynamic corrosion test, H₂ evolution test to measure corrosion rate and performance.

Experimental

For many years, the material used in the clinical applications is mainly include stainless steel, cobalt, chromium and titanium alloys. Because of high mechanical strength and toughness are preferred [1]. However permanent metallic implant possesses some problems, the first is incompatibility of mechanical properties of alloy and natural bone for example metal have greater elastic modulus to that of bone under in-vivo conditions.

The mechanical mismatch between bone and implant causes shield phenomenon called stress shielding because of the stress shielding, the Implant carries large amount of bulk load and the surrounding bone tissue experiences a reduced load stress, this reduce the stress shielding. The alloy at permanent metallic implant such as CO-Cr-MO and Ti-6Al-4V have been manufactured into porous forms to get matched modulus with natural bone for production of such kind of alloy[5,6].

Various methods are available such as sintered metal powder, gas injection to metal melt, plasma spraying use of fuming agent. But the development of porous metallic implant possesses some limitations such as brittleness, impurity of phase and limitation on size and shape and distribution of porosity. Also the permanent implant suffers with mechanical and corrosion with long term implementation in body. This result in releasing of toxic metal ion such as chromium, nickel and cobalt in body, which can trigger the undesirable immune response[7,8].

Field Survey

Field work is necessary while studying any new activity; as our project part it is essential to know common problems of people in which exact implants were fixed due to various reasons.

The current treatment using traditional nondegradable biocompatible materials. In the present, the biodegradable implants are being considered as the alternative for traditional implants. Biomaterials are mainly classified as polymers, ceramics, bone cements. But the mechanical implants prefer for their mechanical strength, toughness with nontoxicity and allergy free elements are composed. The mechanical mismatch between bone and implant causes shield phenomenon called stress shielding because of the stress shielding, the Implant carries large amount of bulk load and the surrounding bone tissue experiences a reduced load stress, this reduce the stress shielding. The alloy at permanent metallic implant such as CO-Cr-MO and Ti-6Al-4V have been manufactured into porous forms to get matched modulus with natural bone for production of such kind of alloy.

There common problems caused by traditional using implant material like Stainless steel and Titanium alloys like Pain due to climatic changes pain due to heavy work during daily routine, heaviness effect/ inertia effect, external impact pain, swelling, other (Irritation, bleeding from implanted area etc.)

We found out of 10 people have common problems like pain due to climate change, heaviness effect, pain due to external impact.

Classification of Mg-based biodegradable metals

Development of Mg based biodegradable metals

1. *Pure Mg*
2. *Mg-Ca and Mg-Sr based alloy systems*
3. *Mg-Zn based alloy systems*
4. *Mg-Si based alloy systems*
5. *Mg-Sn based alloy systems*
6. *Mg-Zr based alloy systems*
7. *Mg-Al based alloy systems*
8. *Mg-Y and Mg-REE alloy systems*

Novel structure design for Mg based biodegradable metals

1. *Porous structure*
2. *Composite structure*
3. *Ultrafine grained structure*
4. *Glassy structure*

Methodology

The detailed additional literature will be reviewed on biodegradable implants. We conduct the field survey. By studying various biomaterials and option for biomaterials and considering their biocompatibility, some materials are preferred for various test purpose. The certain common alloying elements are considered for the test while selecting materials. So we predict corrosion related property of material composition during test.

We studying the body mechanism and healing process, we observed that the biodegradable implant corrodes in human body fluid and is replaced by healing tissue. As per that process the sample preparation and testing taken. After testing, comparison of results obtained by implementing biodegradable materials with previous implant. We have shortlisted following materials for further research purpose.

1. AZ81
2. AM50

Results and Discussion

Different Tests

1. *Immersion Test*

Result

Sample	Weight (gm)		Corrosion Rate (gm/mm ² .sec)
	Before	After	
AZ81	10.366	10.364	8.3438×10^{-8}
AM50	7.246	7.133	26.06×10^{-10}

Discussion

For 1 day of immersion test AM50 alloy shows corrosion but these corrosion is very less than AZ81 alloy. AZE81 alloy has more corrosion than AM50

2. Mechanical Test

The charpy impact test also known as Charpy V-notch test is a standardized high strain-rate test which determines the amount of energy absorbed by the material during the fracture. Tests are done according to ASTM-E-23.

Material	Energy(Joule)	Strength(j/cm ²)
AZ81	3.83	4.8
AM50	4.9	6.13

3. Electrochemical Impedance Spectroscopy (EIS) Test

4. Haemolysis Test

Conclusions

We studied different biomaterials with their properties. We selected biodegradable Mg alloys like AM50, AZ81 and. We studied these materials with their mechanical, chemical, biocompatibility and corrosion tests. We can successfully replace conventional biomedical medical implants to the Mg-based biodegradable medical implants also we can achieve good strength and temporary support to the injured bone while healing process of bone. Mg has shown a great potential as a material for bioabsorbable implants. Although a substantial amount of research has been performed on the use of Mg and its commercially available alloys for biomedical applications, further research is needed to fully evaluate the potential of research grade Mg-based alloys for use in biological implants.

In mechanical test we tested yield strength, ultimate tensile strength and percentage of elongation and found that AZ91 alloy is less above properties than other two alloys. AZ31 is more ductile material which is suitable for biomedical implants. From wet chemical analysis different trace elements are tested and found within particular limit. From EIS test it found that AZ91 has more corrosion resistance than other two alloys. But AZ91 has more aluminum content it may be neurotoxic causing Parkinson's disease, Alzheimer etc. AZ31 has lower corrosion resistance which is suitable for biodegradability. Also we alter its corrosion resistance by surface treatment. H₂ evolution is more in critical period. After which may indicate initial rapid corrosion occurs after that goes on decreasing. Haemolysis test shows quite more haemolysis rate than normal limit; which can be controlled by

surface treatment. Hence AZ50 is most suitable biocompatible material. Its corrosion resistance can be increased by Ca-P coating and causes reduction in haemolysis rate.

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