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AN OVERVIEW OF THE MAGNESIUM AND ZINC BASED BIO-IMPLANTS

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Abstract: Magnesium (Mg) and Zinc (Zn)-based composites and alloys are used in biomedical applications as bioimplants due to its biocompatibility with the human body compared to additional metals, like cobalt-chromium, stainless steel, and titanium alloys. The major disadvantage of magnesium is its faster degradation rate and that of Zinc is its low strength and low plasticity. The behaviour of alloys in terms of corrosion and mechanical properties of composites based on magnesium and zinc are the main topics of this review.

Keywords: Magnesium, Zinc, alloys, Composites, Biodegradable, Bioimplants

I. INTRODUCTION

Due to the increasing world population and advances in medical technology, surgical procedures like bone grafting and dental implants are becoming more commonplace. The qualities and uses of materials in biological systems, such as tissue and organ replacement—materials that serve as stand-ins for various bodily parts—are the subject of biomaterials research. Synthetic and naturally occurring polymers are two of the most promising biological materials that have been employed extensively for organ regeneration. One of the primary disadvantages of polymers in biomedical applications, however, is the in vivo inflammation that results from their degradation process. Although Co- Cr, Stainless steel, and titanium alloys are stiff and strong medical implants, utilising them as a replacement for some body parts could have harmful consequences on the body, such as the Stress Shield effect and poisonous ion release from corrosion. Therefore, choosing the right material is essential for a successful implant. Recent developments have demonstrated the numerous advantages of using biodegradable materials for implants, such as magnesium, zinc, and their alloys.

II. PROPERTIES OF MAGNESIUM AND ZINC

Magnesium is the ninth most plentiful element on Earth and ranks tenth in the human body in terms of mass. With a density of 1.738 g/cm^3 and an alloy density ranging from 1.75 g/cm^3 to 1.85 g/cm^3, it is regarded as one of the lightest metallic elements and is comparable to human bone. One of magnesium metal's greatest qualities as an implant material is that it breaks down under physiological settings, preventing the need for repeated surgeries to replace the implant after recovery. Additionally, any extra magnesium that may arise from corrosion can be eliminated by the urine. When magnesium is included into implants, the human body tolerates the material without becoming intoxicated.

III. MAGNESIUM AND ZINC ALLOYS AS BIOMATERIALS

The coefficient of elasticity and density of magnesium and alloys of magnesium are comparable to those of human bone. By using them in this way, the Stress Shield effect—which leads to bone resorption and subsequently implant loosening—may be mitigated. It is frequently necessary to perform further, intricate revision procedures to remove or replace these implant failures. Moreover, magnesium is a non-toxic, biocompatible substance that the human body can bio resorb. Zn's usage as a therapeutic biodegradable material is limited by its poor hardness (around 25 Hv), 0.3% elongation, and insufficient strength (20 MPa) in terms of mechanical characteristics. When immersed in simulated environments, the deterioration rate of Zn-based alloys is around a fifth that of pure magnesium.

A matrix phase (-Zn) and secondary phases, known as intermetallic phases, which are often hard and brittle, make up the majority of the microstructure of zinc alloys. These intermetallic phases, as well as their volume fractions, sizes, and distribution within the Zn matrix, have a substantial impact on the mechanical properties of zinc alloys. The manufacturing and processing techniques used also affect these microstructural features. Similarly, the primary magnesium matrix and numerous secondary phases, which are primarily dispersed along the grain boundary, make up the microstructure of magnesium alloys. By dispersion strengthening, these secondary phases, which arise from the magnesium matrix at grain boundaries, can increase the strength of magnesium alloys. The distribution and concentration of secondary phases have an impact on how magnesium alloys behave as they corrode. An even and consistent dispersion of secondary phases considerably enhances the magnesium alloys' resistance to corrosion. Magnesium alloys are more ductile, formable, and strong than zinc alloys. Additionally, magnesium alloys have an elastic modulus of 45 MPa, which is comparable to the 10–30 GPa of natural bone. But still, due to their different electrode potentials of 2.37 V and 0.76 V, zinc corrodes more slowly than magnesium.

Since Mg and Zn are biocompatible, combination of properties of both these elements were able to improve the limitations of their pure form. Gravity die casting was used by Incesu and Gungor (2020) to make six distinct Mg-Zn-Ca alloys, also known as ZX alloys. With a yield strength of 121 ± 2.1 MPa, a tensile strength of 226 ± 3.7 MPa, an elongation of 4.1 ± 0.2%, and an immersion corrosion rate of 0.062 mm/year, the hot rolled ZX10-h (Mg-0.94Zn-0.16Ca) alloy possesses acceptable attributes. In place of Ti clips, Yu et al. (2020) created a novel kind of hemostatic clip made of alloy Mg-3Zn-0.2Ca-0.5Y. By micro-alloying Ca and Y, Wang et al. (2021) created a novel Mg-Zn-Ca-Y wrought alloy (ZXW600). When this alloy was processed appropriately, it demonstrated an exceptional excellent strength and ductility combined at both room temperature and increased temperatures.

IV. MAGNESIUM AND ZINC COMPOSITES AS

As the name suggests, a composite is made up of at least two parts, such as reinforcement and matrix. All of the constituents of biodegradable composites must be biocompatible, biodegradable, and harmless to the human body. Metal matrix composites (MMCs) and biodegradable pure metals are the three categories of biodegradable materials. By selecting the appropriate composite, metal matrix composites, which are biodegradable materials, have good mechanical qualities (ultimate tensile strength, Coefficient of elasticity, and yield strength) and corrosion resistance. All of the components of the biodegradable composites ought to be non-toxic and capable of biodegradation in the human body.

A $Zn_3Mg_{0.7}Mg_2Si$ composite made biodegradable using high-pressure solidification (HPS) was created by Tong et al. in their work. The HPS composite showed uniformly distributed fine $MgZn_2$ granules in a -Zn matrix, according to microstructural analysis. Extensive testing showed that the HPS composite had exceptionally good compression properties, like that ultimate compressive strength of 1181.2 MPa, plastic deformation without breaking or cracking up to 60% strain and compressive yield strength of 406.2 MPa.

Potentiodynamic polarisation experiments revealed that the HPS composite had a corrosion rate of 46.2 m/y, corrosion current density of 3.5 A/cm^2 and a corrosion potential of 0.930 V. The HPS composite degraded at a rate of 42.8 m/y and 37.8 m/y, correspondingly, after being submerged in Hanks' solution for one month and three months, according to tests of immersion. Additionally, compared to the HPS composite, an extract showed good cytocompatibility.

Krishnan et al. (2022) studied the use of biodegradable Composites are mainly made via stir casting and powder metallurgy techniques; powder metallurgy is the most effective way to process composites. Selection of reinforcements is a major factor, as it affects the mechanical as well as corrosion behaviour of Mg-MMC.

In a study by Adetunla et.al, Using the stir-casting procedure, three samples of AZ31 Mg alloy were created: one along with 25% of $CaCO_3$ reinforcement, one with 50% of Calcium Carbonate Powder reinforcement, and one with no reinforcement (as received). By using fluorescence, the chemical composition of the alloy was determined, and its microstructural characterisation was ascertained by SEM. In addition, tests for hardness, corrosion, tensile strength, and impact were conducted to ascertain the mechanical characteristics of the composite materials. In contrast to the AZ31 Mg alloy without reinforcement, the newly produced alloy (AZ31B $Mg/CaCO_3$) exhibits better tensile and hardness properties, suggesting that it has a strong potential of existence used in orthopedic applications where resistance to corrosion is crucial.

V. CONCLUSION

This paper provides a brief idea on bio implants, and biodegradable properties of Magnesium and Zinc. The conducted studies shows that Magnesium and Zinc materials are a vast research area for further studies. Magnesium and Zinc alloys with proper alloying is a better implant material. Similarly, the study also concludes that with the selection of proper reinforcement, Mg and Zn

Composites does show similar properties that are required for bioimplants. Further studies and review could be done on surface coatings over magnesium to improve corrosion. Studies could also be done to find a proper processing techniques like additive manufacturing for processing implants.

Conflicts of Interest: "The authors certify that they have no competing interests with regard to this research."

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