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Fabrication and Characterization of Magnesium Foam using TiH_2 for Bio-Medical Applications

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Abstract
Magnesium (Mg) and magnesium alloys are used for biomedical applications (e.g., Fracture fixation) since they have good mechanical properties, biocompatibilities, and reduced weight properties. The cellular structure of foam metals dissimilar to the bone; hence, magnesium foam can be used for biomedical applications. Fabrication of magnesium is a tough job due to its high risk of catching fire during the fabrication process and its low melting point. Powder metallurgy is one of the methods for fabricating Magnesium foam. Magnesium is blended with Titanium Hydride at various quantities, preformed, compacted, and cured to prepare the metal foam. The porosity and structure of the prepared metal foam are found out by SEM analysis; also hardness test is carried out. Metal foam is abundantly used in brakes absorber and a shock absorber, which is found in automobiles. Metal foam is used in automobiles. In addition, the metal, which is foamed, has good vibration resistance, disassembly, and other perfect properties when compared with foamed ceramics. Therefore, studying the compression deformation character and absorption of energy property of magnesium foam is essential.

Keywords: *Magnesium foam, Cellular structure, Powder metallurgy, SEM analysis, Titanium Hydride Deformation, Microhardness test.*

I. INTRODUCTION

In structure and functional materials, porous materials have excellent properties than solid materials, which broaden the fields of research and application of foam materials. Magnesium metal has several favors, such as specific strength, high modulus elasticity, stiffness, good defense noise, and excellent vibration-reducing property. The density of pure magnesium is 1.74 g/cm3, which is one of the lightest metal used in industrial applications. Magnesium foam can soak up energy due to its specific structure. When compared with foamed plastics, foamed metals hasa large melting point, high-temperature stability, superior weather-fastness, and harder aging. As the structural material of impact absorbing energy, it improves vibration in vehicles and collision safety of automobiles. The closed-cell magnesium foam is prepared, and its steady compressive properties were studied by Yong, etc., and they established that the porosity of magnesium foam increases from 53.0% to 71.10%, which results in yield strength decreasing from 27.1MPa to 4.2MPa and absorption of energy decreasingfrom12.7MJ/m3 to 4.2 MJ/m3. The magnesium foam with 40%-50% porosity was prepared by the sun, etc., with potassium of magnesium substrate to enhance the corrosion resistance of the matrix.

II. MATERIALS AND METHODS

A. Magnesium

Magnesium foam alloy is prepared successfully with the help of vacuum filtration by Li et al., and constant compressive properties of metal foam alloy were studied under static load. When it comes to metal foam, research is roughly based on aluminum foam and its alloy. However, research on metal foam material is very later. In addition, the research process and the progression parameters have a huge power on the structure, which affects the performance, but the detailed mechanism in the process has not been studied methodically. At present, powder methodology with a space holder method was to prepare magnesium foam materials to attain excellent absorption of energy of magnesium foam, which can be applied to shock absorber so that it improves the safety and steady of automobiles. A foam metal is a cellular arrangement consisting of a hard metal filled with gas pores comprising a huge portion of the capacity. The pores can be conserved (closed-cell foam) or interconnected (open-cell foam). The significant attribute of metal foams is very high porosity: typically, only 5.25% of the volume is the support metal. The potential of the material is owing to a new law called square-cube law. Metallic foams naturally keep hold of some physical properties of their base material. The foam, which is made from non-flammable metal leftovers non-flammable and can usually be cast-off as the base material. The coefficient of thermal expansion is alike. The thermal conductivity is expected to be reduced. Even though a lot of patents explain sufficient topological structures, constitutive materials, and manufacturing methods, metal foams cannot be measured as a product, and somewhat a small number of profitable producers are existing universal.

Open celled metal foam can be worn in heat exchangers stream dispersion and frivolous optics. The cost of the material, which is high, generally confines its use to highly developed technology, aerospace, and manufacturing. Fine-scale open-cell foams, with cells lesser than be able to be seen by yourself, are used as large temperature filters in chemical manufacturing. Foams are used in condensed heat exchangers in such a way to enlarge heat convey by the cost of controlled pressure. Mainly models of these supplies utilize idealized and cyclic structures with the averaged macroscopic property. Metal sponges have extremely big surface area per unit mass, and catalysts are frequently created into metal sponges, such as palladium black.

Metals like osmium and palladium hydride are symbolically called "metal sponge," although this expression is concerning their property of binding to hydrogen than the physical structure. The closed-cell metal foam was reported in 1926 by Meller in a French patent anywhere foaming of light metals, either by inert gas injection or by blowing agent, was suggested. Closed-cell metal foams are first and foremost used like an impact-absorbing material. Metal foams stay misshapen once impact and stiff and are commonly anticipated to be low weight structural material. Closed-cell foams seize on to the fire conflict and recycling impending of other metallic foams but add the property of floatation in aqueous. For instance, the mechanical potency, rigidity, and absorption of energy of metallic foams are a great deal than those of polymer foams. They are thermally and electrically conductive, and they control their mechanical properties at much higher temperatures than polymers. Besides, they are generally steadier in an unkind environment than polymer foams. As disparate to ceramics, they can collapse plastically and soak up the energy.

Magnesium metal has a bunch of positives such as stiffness, good modulus elastic, high-quality defense noise, high specific strength, and outstanding vibration, reducing performance. The density of pure magnesium is 1.74 g/cm3, which is found in industrial applications. Magnesium foam can soak up the energy of its definite structure. Comparing to foamed plastics, foamed metal hasa superior melting point, large temperature stability, improved weather fastness, harder aging, metal has improved vibration resistance, extra suitable installation, disassembly, and other excellent properties compared with foamed ceramics. The compressive warp in metallic foams takes place in both elastic form and plastic form, e.g., collapse, buckling, bending,etc. These behaviors contain absorption of energy and impact defense fields. The increase in the damping ability of the cell wall materials is supposed to enhance the absorption capacity of the foams. Hence magnesium (Mg) foams are beneficial than aluminum (Al) foams due to the excellent damping properties of magnesium.

On the other hand, powder metallurgy wouldexist, for the most part, appropriate routes for manufacturing Mg foam due to its large chemical activity in the air. Powder metallurgy technology was investigated in the present study in conditions of the space-holder system with the hope of acquiringan eye-catching processing skill. Foams are usually prepared by injection of gas or by the addition of a foaming agent into molten metal. The resulting Mg foams are moreover estimated to have comparatively more precise mechanical properties and are used in a lightweight and crush-worthless arrangements. Melts be foamed through producing gas froth in the material. Usually, froth in molten metal is extremely optimistic in the high-concentration liquid and go up rapidly to the surface. This increase is slowed by raising the viscosity of the molten metal by the accumulation of ceramic powders to figure stabilizing particles in the freeze or through other resources. To steady the molten metal froth, large temperature foaming agents are necessary. The amount of the pores is typically 1 to 8 mm. This is professed "powder route" of foaming, and it is almost certainly the most recognized. After metal (e.g., aluminum) powders and foaming agent (e.g.TiH_2) have been varied, they are condensed keen on to compressed, solid precursor, which can be available in the form of a billet, a sheet, or a wire.

Manufacturing of precursors can be completed by an arrangement of materials foaming processes, such as powder imperative, flat rolling, and extrusion. While the majority of patients practiced subcutaneous gas cavities, which are caused by speedy implant oxidization, the majority of patients had no ache, and nearly no infections were noticed throughout the postoperative record. Industrial attention in magnesium alloys be based on a physically powerful order of weight decline of shipping vehicles for improved fuel effectiveness, so superior strength and improved ductility and corrosion conflict are required. Another way, biomedical magnesium alloys need suitable mechanical properties, proper degradation rate in physiological surroundings, and what is mainly important is bio-security to the human body. Other than the basic application of viable magnesium alloys to the biomedical field, the latest alloys are supposed to intend in view of nutriology and toxicology. A fresh powder metallurgy technology is based on blending-pressing-sintering that can be effectively applied to produce open- cellular Mg foam. A convenient porosity varied from 40% to 80% can be attained by altering the quantity fraction of the foaming agent, and the pore size from hundreds of micrometers to several millimeters, and the pore shape can be accomplished by choosing a suitable agent. The investigation of important manufacturing parameters shows that it should be more optimized when the compacting pressure is in 200 – 300 MPa, and the sintering temperature is in 610 – 630 °C. As a lightweight metal with mechanical properties similar to natural bone, a usual ionic presence with major efficient roles in biological systems where they have the potential to be served as biocompatible, degradable inserts for load-bearing purposes. Mg-Ti alloys with titanium matters varying from 5 to 35% were effectively created by mechanical alloying. Spark plasma sintering was recognized as a processing way to strengthen the alloy powders prepared by ball-milling into bulk material exclusive of destroying the alloy structure.

This is a significant finding as this metal stable Mg-Ti alloy can simply be excited up to a maximum of 200C° for a restricted time exclusive of getting the stable state of divided magnesium and titanium. The greater corrosion performance of Mg80-Ti20 alloy in pretending physiological surroundings was exposed through the hydrogen evolution test, where the corrosion speed was considerably decreased when compared to pure magnesium, and electrochemical measurements exposed an enlarged potential and resistance measure up to clean magnesium. Thus, Mg-Ti alloys can be developed and merged while achieving improved corrosion resistance and upholding compatibility. Biodegradable metals are breaching out to the present prototype in biomaterial science to build up only corrosion-resistant metals. Metals that consist of outline elements offered in the human body are capable candidates for this methodology. The intention of biodegradable implants and coatings be to help tissue restoration and curing in a precise purpose by material deprivation and simultaneous implant alternate through the adjoining tissue. Biodegradable metals have a benefit on existing biodegradable materials, for example, ceramics, polymers, bioactive glasses, etc. This learning is paying attention to biodegradable magnesium and its alloys. Preliminary and latest advances will be explored. Magnesium and its alloys are usually well-known to humiliate in aqueous surroundings via an electrochemical reaction (corrosion), which creates magnesium hydroxide and hydrogen gas.

Hence, magnesium corrosion is moderately insensible to a mixture of oxygen concentrations in aqueous solutions, which take place just about implants in various anatomical locations. Magnesium hydroxide mounts upon the underlying magnesium matrix as a corrosion protective layer in water, but once the chloride concentration in the corrosive surroundings climbsabove 30 mmol/l, magnesium hydroxide starts to transfer into extremely soluble magnesium chloride. Hence, rigorous pitting corrosion can be experiential on magnesium alloys where the chloride substance of the body fluid is about 150 mmol/l. The corrosion structure of magnesium alloy belongs to the alloy chemistry and the ecological conditions. At present, explored magnesium alloys were attained off-the-shelf for sale ordinary alloys or alloys, which can be effortlessly cast. Magnesium mixtures are used as intractable material in heater linings for creating metals, glass, and cement. With a density of only two-thirds of the, it has countless applications in cases where weight-reducing is important, i.e., in airplane and missile construction. It also has many useful chemical and metallurgic properties, which make it appropriate for many other non- structural applications.

B. Titanium Hydride (TiH_2)

Titanium hydride usually refers to the inert compound TiH_2 and is associated with non-stoichiometric materials. It exists as a steady grey/black powder, which is used as a preservative in the production of Alnico sintered magnets, in the sintering of powdered metals, the manufacturing of metal foam, the manufacturing of pulverized titanium metal, and in explosives. Because titanium hydride (TiH_2) is comparatively steady in the air, titanium hydroxide can also be used to produce hydrogen and titanium hydroxide. Titanium hydroxide can be acquired by treating hydrogen with titanium alloy. Beyond 300 °C, titanium can reversibly soak up hydrogen, and at last, forms a compound of the formula TiH_2. If it is excited to above 1000°C, titanium hydride will be completely decomposed into titanium and hydrogen. At an adequately high temperature, the hydrogen-titanium alloy is in equilibrium with the hydrogen. In this process for developing non-stoichiometric TiH_2, titanium metal sponge is deal with hydrogen gas at atmospheric pressure at between 300-500 °C. The absorption of hydrogen is changing the color of the sponge grey/black. The fragile product is earth to a powder, which has a composition of roughly $TiH_{1.95}$.

Titanium hydride is produced by warming titanium powder under flowing hydrogen at 700 °C. Experiment Metallic melts can be foamed in one of three ways: By injecting gas into the liquid metal from an exterior source; by causing the precipitation of gas that was formerly dissolved in the molten metal; by causing gas development in the liquid by admixing gas-releasing blowing agents with the molten metal. An additional method of titanium hydride include electrochemical and ball milling methods. In this study, two test sections were employed. The powder metallurgy with a space holder method is used to set up magnesium foam. The particle size1-3- micron powder is used as raw materials. Titanium as the raw material can seize spaces of pores at lesser temperatures and fester completely at 450 °C to keep away from the reaction with the magnesium powder. The mechanical properties of magnesium foam are largely disturbed by the arrangement of pores, and the particle sizes of raw materials straightforwardly influence the pore structure of magnesium foam. The steps hold mixing, compacting, computing ingredients, and heat treatment.

C. Blending

Magnesium and carbamide powders blended proportionally for 5 min in an agate mortar. Once blending the ingredients well, mixture powders were uniaxially pressed at 200 MPa for 1 min to put out the pressure sufficiently and let alone the bridging effect. The hot-pressing setup is shown.

Fig 1. Weight of Mg sample being measured

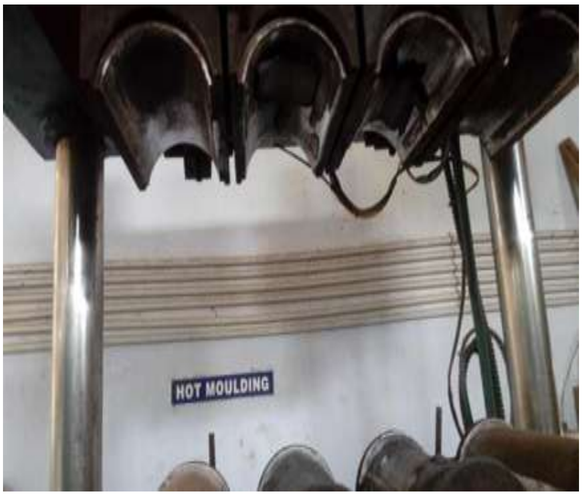


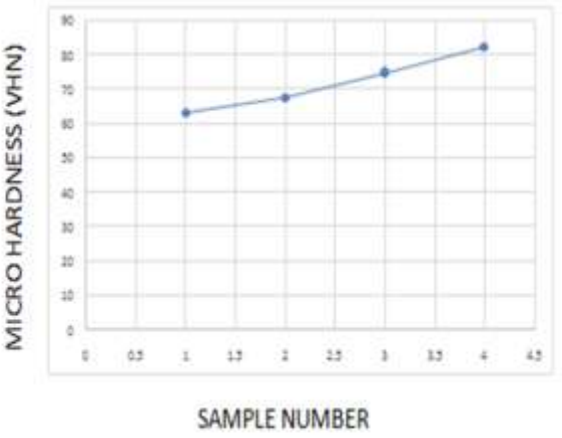
Fig 2. Hot molding/press setup

Fig 3. Material samples after preformed and hot press

Then the samples were heat-treated by argon gas protection. After compacting, the samples are subjected to the curing process. The samples are to be kept inside an isolated vacuum heat furnace. Sintering is done in two steps, at 400 °C for 1hand630°C for 2 hours. After normal cooling, we got the required magnesium foam, as shown in Fig.3. Fig. 1. Weight of Mg sample being measured and. 2. Hot Moulding/Press Setups.

III.HARDNESS AND SEM ANALYSIS WITH FIGURES, TABLES, AND GRAPHS

1. Hardness analysis shows the Vickers hardness data of the AA6061 well-meant using ER5356 filler metal. The following experiments were carried on a Micro- Hardness Tester, Model HM113made by MITUTOYA, Japan. The Vickers hardness values measured from the weld joint center (0 mm) and are measured progressively in the horizontal Y-axis for all four of the samples up to 5 mm in length from the joint center. Hardness values are taken from the face of the sample. We can infer from the hardness test results that hardness increases with more composition of Titanium Hydride and hardness increases linearly in straight line.



Graph 1.Graph for the result of hardness test on various samples of magnesium foam.

Fig 4.Microhardness testing machine

Sample number	Hardness (HV)
1	**63.5**
2	**67.9**
3	**75.2**
4	**82.6**

Table 1.Microhardness test results of all four samples of Mg-TiH_2

We can infer from the hardness test results that hardness increases with more composition of Titanium Hydride, and hardness increases linearly in a straight line from samples 1 to 4.

2. SEM analysis test results of four samples: The SEM analysis for all the four samples of-$TiH_2$was carried out, and its microcellular structure was studied, as shown in the below figure. Each sample of magnesium titanium hydride foam shows different SEM analysis images with a different magnification of the presence of porosity inside.

Fig 6.SEM analysis experimental setup

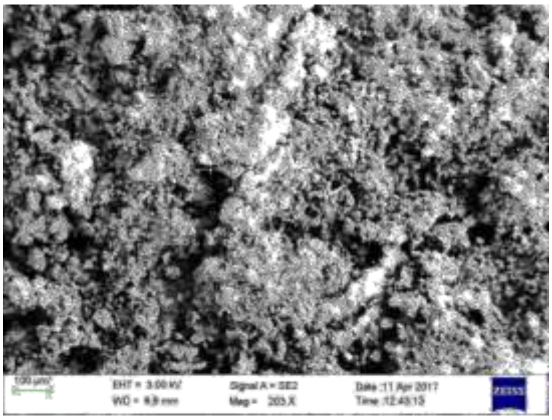


Fig 7. SEM image of sample 1 under magnification of 203x

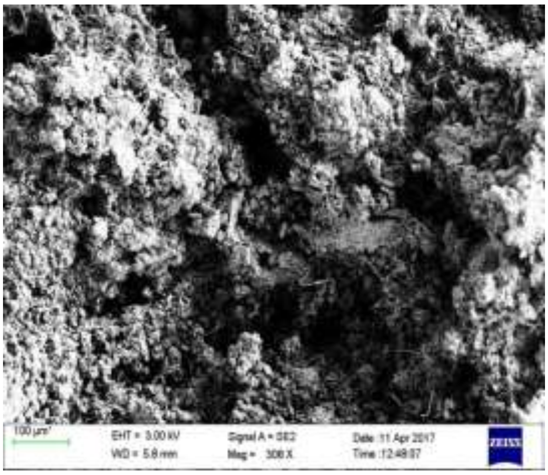


Fig 8. SEM image of sample 2 under magnification of 308x

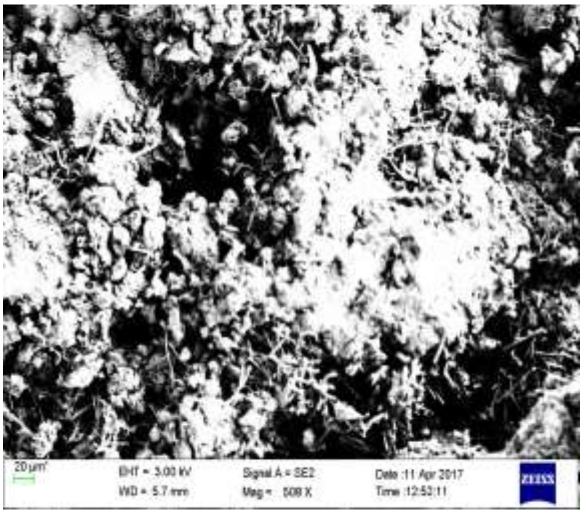


Fig 9. SEM image of sample 3 under magnification of 508x

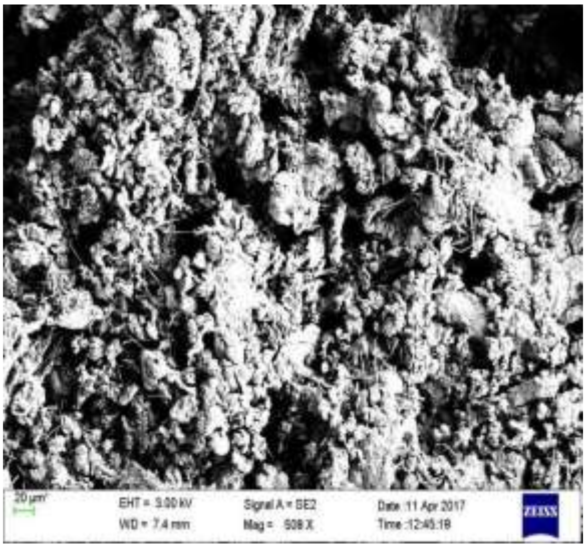


Fig 10.SEM image of sample 4 under Magnification of 508x

We can infer from fig 7.2-7.5 that the porosity of the microstructure was maximum at sample 4 and minimum at sample 1. So we can conclude that the porosity of magnesium foam increases with an increase of Titanium hydride as a foamingagent.

IV. CONCLUSION

The porosity of Magnesium alloy increases with an increase of Titanium hydride as the foaming agent. Highly porous Magnesium foam was fabricated by using the blending-pressing- sintering method with Titanium hydride as the foaming agent. A curing process of about 600°C is carried out at least 2 hours to obtain the final structure of Magnesium foam samples, and was inferred using SEM analysis that as the percentage of Titanium hydride increases, the porosity of structure also increases, as shown in sample 4 where Titanium hydride composition was 3% and showed maximum porosity in its structure.Micro hardness test for all samples was conceded to define the strength of the materials in which sample 4 showed a high hardness of 82.6 HV, and sample 1 showed the least hardness of 63.5 HV. From this, we can infer that hardness was increased with an increase in the percentage of Titanium hydride.

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