UTM Faculty of Mechanical Engineering UNIVERSITI TEKNOLOGI MALAYSIA THE ENGINEER STORY

e-ISSN: 3009 - 0792 Volume 12, 2024, 13-16

MECHANICAL PROPERTIES AND CORROSION STUDY OF MAGNESIUM/ IRON/ HYDROXYPATITE COMPOSITE WITH HYROXYPATITE SOL-GEL COATED FOR BONE SCAFFOLDS APPLICATION.

Mohammad Taufiq Al Hakim Bahrudin [1,*], Abdul Hakim Md Yusop [2]
[1] Material Research and Consultancy Group (MRCG), Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia.
[2] Department of Material, Manufacturing and Industry), Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia.
[*] Corresponding author: mta.hakim@graduate.utm.my

ABSTRACT

In this paper the mechanical properties of the Mg/Fe/HAp composite been analysed by the compression test. As the composition iron (Fe) increased on the composite the compressive strength was increase. However, the 10wt% of iron is the optimum composition of iron in the composite with the compressive strength 260.8813 MPa. On top of that, the corrosion study of the fabricated composite was studied by potentiodynamic polarization whereas the Fe composition increased the corrosion rate of the fabricated composite increased to micro-galvanic effect. Thus, this led to the corrosion studies of the coating for reducing the corrosion rate of the highest mechanical properties composite which is Mg/10Fe/5HAp composite.

KEYWORD

Composite, compression strength, corrosion, biomaterials

INTRODUCTION

A bone defect is a shortage of bone tissues in the area it normally existent. This can be consequence of different condition including severe trauma, infection or natural bone disease such tuberculosis, osteoporosis and tumour invasion as reported from Li et al., (2019). Thus, these issues required surgical procedures such bone grafting, distraction osteogenesis or an artificial bone replacement. Globally, according to Mailou et al., (2019) estimated 2.8 million orthopaedic procedures were performed annually. From the statement, it brings an important issue for researchers to discover more about human bone studies. Bone implant is one of the bone treatments which also known as bone graft or bone substitute used to replace and repair damaged bone tissues. Wirth et al., (2012) and Sanz et al., (2019) stated the purpose of bone implant is to promote bone healing and regenerative by providing structural support, enhancing stability and facilitating the integration of the new bone growth. In current clinical studies, the second surgery needed to remove the bone implant after bone healing period meet healthy bone characteristics. Those need a higher cost as well as increased the risk of infection to the patient. This type of bone implant was a non-biodegradable bone implant mainly made from non-biodegradable metal such titanium, chromium and cobalt.

To reduce those problems, biodegradable implants were studied and some of them have commercially been applied in this biomedical industry. Thus, the novelty of this research focused on the combination of magnesium (Mg), iron (Fe) and hydroxyapatite (HAp) as a metal matrix composite with the enhancement of hydroxyapatite sol-gel coating for bone scaffold implantation in trabecular or cancellous bone environment. The used of Mg/Fe/HAp composite as biodegradable bone scaffolds along with the enhancement bioactive coating HAp/PVA/PLA has not been proposed and rigorously studied yet. Previous studies that related to bone scaffold implantation were only performed on the mechanical properties and the corrosion study on the Mg-Fe composite without any additional bio ceramic. However, in this study the mechanical properties, corrosion study and in vitro cell viability test of Mg/Fe/HAp with addition HAp/PVA/PLA coating been conducted and analysed comprehensively.

MATERIAL AND METHODOLOGY

Magnesium (Mg) powder with minimum particle size of 250 microns and 99.8% of purity was purchased from GoodFellow Cambridge Limited,England. The Mg powder was stored in the flammable chemical store due to the characteristic of flammable solid. For an Iron (Fe) powder with 6-to-8-micron particle size were purchased also from GoodFellow Cambridge Limited, England with 99% purity. On top of that, hydroxyapatite (HAp) powder was purchased from Sigma-Aldrich, USA with purity for analysis ≥ 90% with semi crystalline structure. This powder was stored in the chemical stored at room temperature as indicated from the manufacture company. Then, the Phosphate Buffer Saline (PBS) powder was purchased from Sigma-Aldrich, USA. Since PBS in powder form it need to be dissolved with ratio of 1 pouch of PBS equivalent to 1ml of distilled water resulting 0.01M of PBS solution with pH7.4.

This composite fabrication was performed by powder metallurgy method. First the material powder was weight based on the desired composition as been tabulated on Table 1.1. 0.5-gram total of weight per sample were fabricate and each sample has been mixing by mechanical mixing method with 80rpm speed for 10 hours. Then the mixed powder was compressed into the cylinder mould with 7.5 tome compression load for 2 minutes holding time. The last process of the composite fabrication is sintered process where all the fabricated pallet sample were sintered with argon gas flow at 450°C at 4 hours holding temperature.

Table 1: Terms used on the tested material.

Terminology	Indication
Pure Mg	Porous Mg pallets
Mg/1Fe/5HAp	94 wt% Mg, 1 wt% Fe and 5 wt% HAp
Mg/5Fe/5HAp	90 wt% Mg, 5 wt% Fe and 5 wt% HAp
Mg/10Fe/5HAp	85 wt% Mg, 10 wt% Fe and 5 wt% HAp
Mg/15Fe/5HAp	80 wt% Mg, 15 wt% Fe and 5 wt% HAp

For the next process is the fabrication of the Sol-Gel coating solution. Firstly, the polymers powder of PVA were dissolved in distilled water at 170°C for 30minutes. At the same time the PLA powder was also been dissolved in acetone at 50°C for 30minutes. Afterward, the PVA solution ere poured into the PLA polymers for mixing process between both polymers for another 10 minutes at 100°C. Then, the hydroxyapatite powder been mixed together for another 30 minutes at 100°C. The final Sol-Gel HAp has been fabricated thought the process.

RESULT AND DISCUSSION

As from the fabricated composite, the mechanical properties in term of the compression were tested. From the Figure 2 it shows the stress-strain compression curved where the trend showed as the iron composition increased the compression strength also increased from 230.5044MPa for pure Mg to 260.8813 MPa for the 10wt% of Fe in the composite. This 10wt% of Fe is the optimum composition due to at 15wt%Fe due to it found the high agglomeration from the EDS analysis. This high agglomeration was causing a cracking on the sample due to the different of the thermal gradient effect on Figure 3. On top of that, this were also increased the porosity of the 15wt%Fe composite where the Fe particle agglomerate. This, accelerating the high sliding effect and reduced the compression test of the sample.

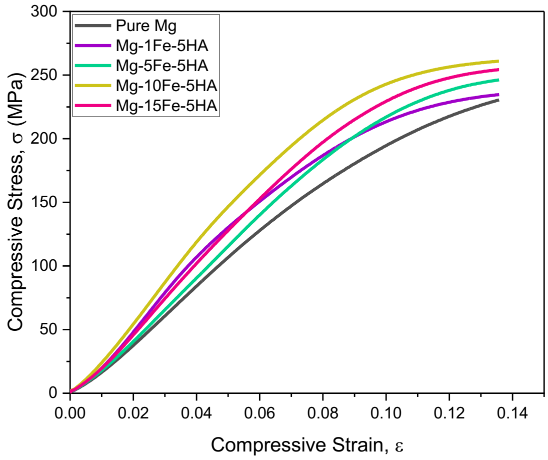

Figure 2: Compression Test of the fabricated composite.

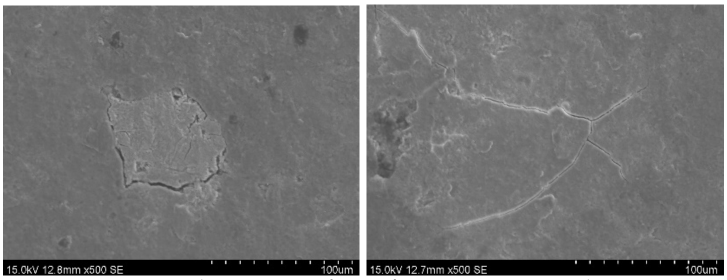

Figure 3: Cracking on Mg/15Fe/5HAp composite by SEM.

In term of the corrosion study for fabricated composite, Figure 4 show the tefal curve of the fabricated composite where it has been extracted the data on the Table 2. Pure Mg has the lowest corrosion rate, but as the addition of Fe composition on the composite it showed the increased trend of the corrosion rate. This is due to; high composition of Fe between the Mg matrix composite will increase the micro galvanic corrosion on the fabricated composite. Thus, the study of the coating was cooperated in this part where the 10wt%Fe has desired the high compression strength of the composite and the coating analysis will reduce the corrosion rate of the fabricated sample.

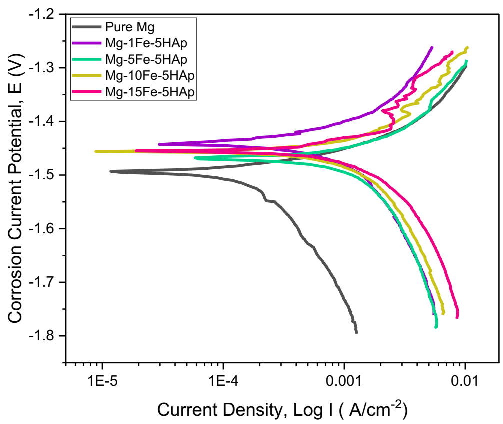

Figure 4: Tefal curved of the fabricated composite by Potentiodynamic Polarization

Table 2: Corrosion analysis of the fabricated composite.

Type of Sample	Corrosion Rate (mmpy)	icorr (uA)	Ecorr (V)	Density (g/cm^3)
Pure Mg	4.3913	192.3193	-1.4930	1.7400
Mg/1Fe/5HAp	20.7688	937.8503	-1.4430	1.7941
Mg/5Fe/5HAp	23.6493	1103.4038	-1.4680	1.8537
Mg/10Fe/5HAp	26.3655	1283.3513	-1.4560	1.9339
Mg/15Fe/5HAp	32.7666	1667.0911	-1.4550	2.0214

CONCLUSION

In conclusion, the Mg/Fe/HAp composite were archived the mechanical compression strength of for the application of the bone scaffold with the optimum composition of iron is 10wt%. However, due to the high corrosion rate as the Fe composition increase the coating corrosion study need to be performed to reduce the corrosion rate of the Mg/10Fe5HAp composite below the pure Mg corrosion rate.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the Malaysian Ministry of Higher Education and University Teknologi Malaysia (UTM) under the UTM Encouragement Research (UTM-ER) (Q.J130000.3824.31J89) and Fundamental Research Grant Scheme (FRGS).

REFERENCE

Li, J. W., Du, C. F., Yuchi, C. X., & Zhang, C. Q. (2019). Application of Biodegradable Materials in Orthopedics. Journal of Medical and Biological Engineering, 39(5), 633–645. https://doi.org/10.1007/S40846-019-00469-8/METRICS

Mailoo, V. J., Srinivas, V., Turner, J., & Fraser, W. D. (2019). Beware of bone pain with bisphosphonates. BMJ Case Reports CP, 12(3), e225385. https://doi.org/10.1136/BCR-2018-225385

Sanz, M., Dahlin, C., Apatzidou, D., Artzi, Z., Bozic, D., Calciolari, E., De Bruyn, H., Dommisch, H., Donos, N., Eickholz, P., Ellingsen, J. E., Haugen, H. J., Herrera, D., Lambert, F., Layrolle, P., Montero, E., Mustafa, K., Omar, O., & Schliephake, H. (2019). Biomaterials and regenerative technologies used in bone regeneration in the craniomaxillofacial region: Consensus report of group 2 of the 15th European Workshop on Periodontology on Bone Regeneration. Journal of Clinical Periodontology, 46(S21), 82–91. https://doi.org/10.1111/jcpe.13123

Wirth, A. J., Müller, R., & Van Lenthe, G. H. (2012). Augmentation of peri-implant bone improves implant stability: Quantification using simulated bone loss. Journal of Orthopaedic Research, 30(2), 178–184. https://doi.org/10.1002/JOR.21532