# PROPERTIES OF BIOCOMPATIBLE Mg-Zn ALLOY BASED HYBRID COMPOSITE FABRICATED BY POWDER METALLURGY

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**by**

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| Ar | Argon |
| BPR | Ball to powder weight ratio |
| BSE | Back scattered electron |
| EDX | Energy Dispersive X-ray |
| FESEM | Field Emission Scanning Electron Microscopy |
| MA | Mechanical alloying |
| MMC | Metal Matrix Composite |
| PM | Powder Metallurgy |
| XRD | X-ray Diffraction |
| Co-Cr-Mo | Cobalt-Chromium-Molybdenum |
| HAP | Hydroxyapatite |
| $Al_2O_3$ | Alumina |
| Ti | Titanium |
| NaCl | Sodium Chloride |
| Al | Aluminum |
| Mg | Magnesium |
| Ca | Calcium |
| Zn | Zinc |

| | |
|---|---|
| Mn | Manganese |
| Ta | Tantalum |
| Nb | Niobium |
| Ni | Nickel |
| Li | Lithium |
| Zr | Zirconium |
| SiC | Silicon Carbide |
| RE | Rare Earth |
| RDA | Recommend Diet Allowance |
| SBF | Simulated Body Fluid |
| $Mg(OH)_2$ | Magnesium Hydroxide |
| ROM | Rule of Mixture |
| HBSS | Hanks Balanced Salt Solution |
| $Mg^{2+}$ | Magnesium ion |
| HCP | Hexagonal Closed Packed |
| CaO | Calcium Oxide |
| PLLA | Poly (lactic acid) |
| PGA | Poly (glycolic acid) |

## LIST OF SYMBOLS

| | |
|---|---|
| 2θ | Diffraction angle |
| Hv | Vickers Hardness |
| V | Volume |
| $E_{corr}$ | Corrosion potential |
| $i_{corr}$ | Corrosion current density |
| $T_m$ | Melting temperature |
| MPa | Mega Pascal |
| GPa | Giga Pascal |
| BC | Before Christ |

**SIFAT BIO-SERASI KOMPOSIT HIBRID BERASASKAN ALOI Mg-Zn DIFABRIKASI SECARA METALURGI SERBUK**

## ABSTRAK

Dalam kajian ini bahan logam biodegradasi dan bioaktif magnesium-zink/hidrosiapatit/alumina (Mg-Zn/HAP/$Al_2O_3$) difabrikasi melalui metalurgi serbuk telah dibangunkan. Objektif utama kajian ini adalah untuk mengkaji kesan kandungan dan nisbah berat partikel HAP dan $Al_2O_3$ terhadap sifat mekanikal, kakisan, bioaktiviti dan kehausan aloi Mg-Zn. Serbuk Mg, Zn, HAP dan $Al_2O_3$ dicampur menggunakan pengisar bola tenaga tinggi, dipadat pada 400 MPa dan disinter pada suhu 300˚C. Penambahan kandungan $Al_2O_3$ dari 0 hingga 15 wt. % di dalam hibrid komposit menunjukkan peningkatan kekerasan (57.60 Hv hingga 83.87 Hv) dan kekuatan mampatan (126.48 MPa hingga 244.20 MPa). Berdasarkan ujian polarisasi, 0 wt. % $Al_2O_3$ komposit (iaitu mengandungi 15 wt. % HAP) adalah paling lengai dengan potensi kakisan (-1.604V), dan paling rendah keamatan arus dan kadar kakisan (0.252 $\mu A/cm^2$, 1.25 mm/tahun) hasil daripada pertumbuhan apatit di dalam larutan garam seimbang Hanks (HBSS). Manakala 5 wt. % $Al_2O_3$ (iaitu mengandungi 10 wt. % HAP) menunjukkan rintangan kehausan paling tinggi disebabkan ketinggian kekerasan $Al_2O_3$. Komposit dengan kandungan 20 wt. % (nisbah HAP dan $Al_2O_3$ 2:1) menunjukkan kekerasan rendah (67.03), kekuatan mampatan rendah (138.67 MPa), kadar kakisan tinggi (2.34 mm/tahun) dan rintangan kehausan dengan kehilangan isipadu terendah (4.9 hingga 14.6 x $10^{-4}$ $mm^3$). Keseluruhannya, komposit hibrid dengan penambahan 5 wt.% $Al_2O_3$ dan 10 wt. % HAP pada nisbah 2:1 mempamerkan keputusan yang paling baik untuk aplikasi implant bioperubatan.

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## ABSTRACT

In this study, biodegradable and biactive metallic material of magnesium-zinc/hydroxyapatite/alumina (Mg-Zn/HAP/$Al_2O_3$) hybrid composite fabricated by powder metallurgy was developed. The main objective of this work was to investigate the effects of HAP and $Al_2O_3$ amount of content and weight ratio on mechanical, corrosion and wear behaviour of Mg-Zn based alloy. The powders of Mg, Zn, HAP and $Al_2O_3$ were mixed in a high energy ball mill, compacted under 400 MPa and sintered at 300˚C. The increasing $Al_2O_3$ content from 0 to 15 wt. % in the hybrid composite resulted in improvement in hardness (57.60 Hv to 83.87 Hv) and compression strength (126.48 MPa to 244.20 MPa). Based on polarization test, 0 wt. % $Al_2O_3$ composite (i.e. consist of 15 wt. % HAP) is the most noble with corrosion potential (-1.604 V) and the lowest current density and corrosion rate (0.252 $\mu A/cm^2$, 1.25 mm/year, respectively) due to apatite formation in Hanks Balanced Salt Solution (HBSS). While 5 wt. % $Al_2O_3$ (i.e. with 10 wt. % HAP) shows the highest wear resistance due to high hardness of $Al_2O_3$. Composite with 20 wt. % ceramic (HAP and $Al_2O_3$ with 2:1weight ratio) exhibited low hardness (67.03 Hv), low compressive strength (138.67 MPa), high corrosion rate (2.34 mm/year) and the low volume loss due to wear (4.9 to 14.6 x $10^{-4}$ $mm^3$). Overall, hybrid composite with addition of 5 wt.% $Al_2O_3$ and 10 wt. % HAP at weight ratio 2:1 displayed the best properties, for biomedical implant application.