UNIVERSITI TEKNIKAL MALAYSIA MELAKA

CORROSION BEHAVIOR OF TiAlBN, TiN AND AlN COATING PRODUCED BY MAGNETRON SPUTTERING ON MAGNESIUM SUBSTRATE (USING HANK'S SOLUTION)

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Engineering Materials) (Hons.)

by

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Engineering Materials) (Hons.). The member of the supervisory is as follow:

………………………………

(Project Supervisor)

ABSTRAK

Matlamat projek ini adalah untuk membandingkan sifat kakisan/karat salutan (coating) TiN, AlN dan TiAlBN ke atas aloi magnesium (Mg). Selain itu, sifat-sifat umum salutan yang mempengaruhi kakisan di dalam Mg akan ditentukan. Dalam projek ini, ujian elektrokimia akan dilakukan untuk mendapatkan kesan kakisan oleh salutan ke atas Mg. Tambahan pula, ujian ini memberi persekitaran yang sama seperti persekitaran kakisan/karat. Cecair Hank (Hank's solution) akan digunakan sebagai elektrolit dan kadar kakisan/karat akan dikira melalui ujian ini. Peralatan pencirian bahan seperti 'Scanning Electron Microscopy' (SEM) dan 'Energy Dispersive X-ray Spectroscopy' (EDX) diperlukan untuk melihat permukaan Mg yang terkakis/karat.

ABSTRACT

The aim of this project is to compare the corrosion behavior of TiN, AlN and TiAlBN coating on magnesium (Mg) alloy. Besides, the general properties of coating which influnced the corrosion of Mg are going to be determined. Electrochemical test will be utilized in order to get the effect of corrosion as this test is giving a similar environment as a corrosion environment. Furthermore, Hank's solution will be used as an electrolyte and the corrosion rate will be calculated through the test. Material characterization equipment such as Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectroscopy (EDX) will be used in order to observe the morphology of corroded surface of Mg sample.

DEDICATION

To my beloved parents and friends for all the time I spent away from them while preparing this final year project's report.

ACKNOWLEDGEMENT

Alhamdulillah, I have successfully completed my final year project within the time given. In that period of time, I have gained so much experiences, memories and knowledge through my project. A lot of experiences and unforgettable memories are captured along the way in finishing my project. May those experiences help me in future either in my working life or in my further studies.

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Lastly, million thanks to friends and others who were directly or indirectly in helping and guiding me during finishing this project. Thank you so much for your endless support.

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Ag-AgCl	-	Argentum-ArgentumChloride
Al	-	Aluminium
AlN	-	Aluminium nitride
ASTM	-	American Society for Testing Material
BSS	-	Balanced Salt Solution
CVD	-	Chemical Vapor Deposition (CVD)
DC	-	Direct current
EDX	-	Energy Dispersive X-ray Spectroscopy
HBSS	-	Hank's Balanced Salt Solution
Mg	-	Magnesium
N	-	Nitrogen
PVD	-	Physical Vapor Deposition (PVD)
RF	-	Radio frequency
SBF	-	Simulated body fluid
SCE	-	Saturated calomel electrode
SEM	-	Scanning Electron Microscopy
TEM	-	Transmission Electron Microscopy
TiAlBN	-	Titanium aluminium boron nitride
TiN	-	Titanium nitride
UTeM	-	Universiti Teknikal Malaysia Melaka
XRD	-	X-ray Diffraction
Zn	-	Zinc
$A_{initial}$	-	Exposed sample surface area, cm^2
CR	-	Penetration Rate, mm/y
EW	-	Equivalent Weight, g
E_{corr}	-	Corrosion Potential, V
I_{corr}	-	Total anodic, µA

K_1	-	3.27×10^{-3}, mm g/μA cm yr
K_2	-	8.954×10^{-3}, g cm^2/μA m^2 d
MR	-	Mass Loss Rate, g/m^2d
M	-	Mass, *g*
v	-	Volume, cm^3
i_{corr}	-	Corrosion current density, $\mu A/cm^2$
ρ	-	Density, g/cm^3
α-phase	-	Primary α-phase in magnesium alloy
β-phase	-	eutectic β-phase in magnesium alloy

CHAPTER 1
INTRODUCTION

1.1 Background

In the early of 1950s, magnesium alloys has been widely used in aerospace and automotive industries due to its low density and high strength-to-weight ratio. As the lightest structural metallic materials, their application has been extensively increase especially in vehicle construction and aeronautics field.

It is well known that magnesium and its alloys having the hexagonal crystal structure. Minchen and Weiheim (2000) as cited in Wei Guo K., (2010) claims that their formability at ambient temperature has been affected by the multi-slip planes causing the deforming of the grain boundaries due to stresses from localized slip. In addition, the formation of a thin surface film which is not dense indicates that the underlying metal cannot be completely covered. Thus, they are highly influenced to corrosion (Wei Guo, 2010).

Since the application of magnesium in industries is limited by the corrosion, it is important to improve this weakness by surface modification. In this paper, various coating has been done on magnesium AZ91 by using physical vapor deposition (PVD) methods. PVD is a process where the material is vaporized from solid or liquid form into atom or molecules form. The main categories of PVD methods are vacuum deposition, sputter deposition arc deposition and ion platting. In this project, the coatings will be deposited by using sputter deposition. There are three types of coating which will be focused in this work, TiN, AlN and TiAlBNcoating.

In order to determine the corrosion behavior for each coating, an electrochemical test will be done. The sample will be immersed in simulated body fluid; Hank's solution and the corrosion rate and corrosion potential will be determined. Higher the corrosion potential, better the corrosion resistance for magnesium AZ91. In order to observe the surface morphology of the corroded sample, analytical techniques will be used. Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectroscopy (EDX) is used in order to see the surface morphology of corroded sample.

1.2 Problem Statement

Over the years, magnesium (Mg) and its alloy has been developed as widely used structural materials in many fields due to their mechanical properties such as low density, high strength-to-weight ratio (Wang et al., 2010). Besides, increased in ductility and castability also make them being an industrially accepted for the numerous application.

However, one major problem with the application of magnesium and its alloy is poor corrosion resistance even in moderately aggressive environments (Sudholz et al., 2009). Therefore, to increase the resistance of corrosion on magnesium, surface treatment is needed. Coating is one of the surface treatments which can be done on magnesium. Coating tends to improve surface properties of the substrate such as corrosion resistance, wear resistance, appearance and wettability.

In this works, three types of coating would be deposited on magnesium AZ91 which are TiN, AlN and TiAlBN coating. The most preferable coating due to several properties which increases the corrosion resistance on magnesium will be determined.

1.3 Objectives

The objectives of this project are:

- To compare the corrosion behavior of TiAlBN, TiN and AlN coating produced by magnetron sputtering on magnesium substrate.
- To understand the general properties of coating including surface morphology and chemical composition.
- To evaluate surface morphology of general corrosion on different coatings.

1.4 Scope

This project is to compare the corrosion behavior between TiAlBN, TiN and AlN coating. Only the general properties of corrosion in coating will be discussed. Test method which relates with this project paper, electrochemical testing will be used. The solution which will be used as an electrolyte in the electrochemical testing is a simulated body solution, Hank's Solution. Besides, an observation will be done on surface topography of the sample in order to prove the form of corrosion.

1.5 Project Organization

This project was organized into five chapters:

Chapter 1 is the introduction to this report. This includes background, problem statement, objectives and scope of the project.

Chapter 2 is on literature review which describing the findings of the project, theoretical and methodology before the experimental works start.

Chapter 3 is on methodology which includes experimental procedures and apparatus setup required for the corrosion test. The micrographic observation procedure also will be included.

Chapter 4 includes the results and discussion of the experiment and the observation on the morphology.

Chapter 5 is would like to conclude on overall project. Recommendation for further study also will be discussed in this chapter.

CHAPTER 2
LITERATURE REVIEW

2.1 Magnesium and its Alloy

Having a quarter weights of the steel and a third lighter than aluminium makes magnesium becomes the lightest structural of metal in the world. Magnesium was found 2.8% in sea water and other forms, including Dolomite (CaMg(Co3)2), Magnesite (MgCo3) and Carnallite (KMgCl3.6H2O). These forms have been found in USA, England, Australia, Germany, Russia and Italy (Tapany, 2007). Magnesium with 99.8% purity is readily available but it was rarely used in engineering applications.

According to the ASTM (American Society for Testing Material) system, magnesium and its alloy has been designated by two capital letters followed by two or three numbers.

Table 2.1: Classification of magnesium alloys (Tapan, 2007).

Letters: Stands for the two major alloying elements. *First letter: The highest amount *Second letter: The second highest amount	Example : AZ91 A-Aluminium is the highest amount in AZ91. Z-Zinc is the second highest.
Numbers: Stands for the amount of the two major alloying elements. *First number: The wt% of the first letter element. *Second number: The wt% of the second letter element.	Example: AZ91 9-9 wt% of Aluminium. 1-1 wt% of Zinc.

Some of the commercial magnesium alloys:

1. Mg-Al casting alloys
2. Mg-Al-Zn casting alloys
3. Mg-Zn and Mg-Zn-Cu casting alloys
4. Mg-Zn-Zr and Mg-RE-Zn-Zr casting alloy
5. High temperature Mg casting alloys
6. Wrought Mg alloys

In this project, magnesium with AZ91 will be focused as Mg-Al-Zn system being the most widely used. This is because cast magnesium alloys dominate 85-90% of all magnesium products (Tapany, 2007).

Alloying elements in magnesium intends to produce alloys with high-strength-to-weight ratios. This may suitable in many fields of application such as aerospace, electronics and automobile field. Besides, they have high specific strength modulus and excellent anti shock resistance as they are able to form compounds with negative valence ion rather than solid solution due to strong electropositive in the elements. However, low strength and toughness, low corrosion resistance and easily flammable with oxygen has limits the application of magnesium alloy (Tapany, 2007). Poor atmospheric corrosion resistance and very reactive in the air makes magnesium will be corroded easily. Thus, to improve the adhesion, wear and corrosion resistance of magnesium alloy, a proper surface treatment is necessarily done (Sudagar et al., 2011).

2.2 Corrosion

Low corrosion resistance is one of the limitations in the application of magnesium alloy. This purpose of this project is to determine which of the coating produced by magnetron sputtering is giving better surface treatment for magnesium alloy.

Corrosion can be defined as the degradation of a material due to a reaction with its environment. Corrosion is a destructive attack of a metal by chemical or electrochemical reaction with its environment (Revie, 2008). Up to 1960s, the term corrosion is restricted only to metals and its alloy without incorporating ceramics, polymers, composites and semiconductors. However, in recent years all type of natural and man-made materials is having connection with corrosion, not metal and its alloy alone (Ahmad, 2006).