12/06/2022

טופס הגשת הצעת מחקר

מדעי הסביבה והמים (היערכות לשינויי אקלים ואירועי חרום) 2022

תת תחום: אנרגיה מתחדשת נטולת פחמן

מרכז הפרויקט: ד"ר גיא יהודה בן חמו

נושא המחקר: פיתוח אנודת מגנזיום ליישומי סוללות מגנזיום-אוויר

פרטי הצעה

מספר סימוכין: 0004293
מגיש ההצעה: ד"ר גיא יהודה בן חמו
סוג בקשה: קדם הצעה+מלאה
סה"כ תקציב מבוקש: ILS 741,836

מוסד: המכללה האקדמית להנדסה - סמי שמעון
משך (שנים): 3
מס' מוסדות משותפים: 1

תחום אנרגיה מתחדשת נטולת פחמן

מידע מדעי כללי

נושא המחקר (עברית)

פיתוח אנודת מגנזיום ליישומי סוללות מגנזיום-אוויר

נושא המחקר (אנגלית)

Development of Magnesium anode for Mg-Air Battery

מילות מפתח (אנגלית)

magnesium alloys, Mg-air batteries, Discharge performance, Electrochemical behaviors

תקציר

תקציר המחקר (בעברית)

בעידן של פיתוח בר קיימא וחדשנות אקולוגית, צפיפות אנרגיה גבוהה היא אחת הדרישות הקריטיות לפיתוח אגירת אנרגיה חדשה, כולל פיתוח סוללות. מחקרים מאשרים שלסוללות מתכת-אוויר יש צפיפות אנרגיה גבוהה במיוחד, עמידות והספק ספציפי בהשוואה לסוללות קונבנציונליות. בנוסף, ידידותיים לסביבה, קלות משקל ועלותן נמוכה. סוללת מגנזיום-אוויר היא אחת ממערכות הסוללה האטרקטיביות ביותר ומציגה מתח תיאורטי וצפיפות אנרגיה גבוהים. למגנזיום תכונות פיזיקליות ואלקטרוכימיות, הוא זול, ולכן הוא מועמד אטרקטיבי ליישומי מתכת-אוויר. למרות יתרונות רבים של סגסוגות המגנזיום, קיים פער מדעי/טכנולוגי בשימוש בסגסוגות מגנזיום כאנודה ליישומי סוללות מתכת-אוויר. שתי הבעיות העיקריות של אנודות המגנזיום הן תהליכי הקורוזיה העצמית המהירה באלקטרוליט מימי וקינטיקה אנודית וקתודית נמוכה יחד עם תגובות לוואי. אחת הסיבות העיקריות לבעיות הללו הינה המגוון הקטן של סגסוגות מגנזיום הקיימות כיום והפיתוח שלא התמקד בישימות סוללות מתכת-אוויר. רק מחקר יישומי שיוביל לפיתוח ייעודי של סגסוגת מגנזיום יוכל לצמצם את הפער היישומי הנוכחי. מחקר זה יפתח מספר סגסוגות מגנזיום, בעלות נמוכה, וייבחן את הקשר בין תכולת האלמנטים המסגסגים, תהליכי הייצור, המיקרומבנה והתנהגות הפריקה של אנודת המגנזיום. בנוסף, בתום תהליך הפיתוח, יורכב אב טיפוס לסוללת מגנזיום-אוויר תוך התחשבות בתחולת הסוללה בעתיד הקרוב ובדגש על יישומים ברכבים חשמליים.

תקציר המחקר (אנגלית)

In an era of sustainable development and innovation ecosystem, a high-energy-density is one of the critical requirements for developing new energy storage, including battery technology. Research to date confirms that, Metal-Air Batteries (MABs) have an exceptionally high energy density, durability, and specific power compared to conventional batteries. In addition, they are environmentally friendly, low-cost, and lightweight. The Mg-air battery is one of the most attractive battery systems and presents high theoretical voltage and energy density. Mg has physical and electrochemical properties, is inexpensive, and is an attractive candidate for MABs applications. Despite many advantages of Mg alloys, there is a scientific/technological gap in using Mg alloys as an anode for MAB. The two main issues for Mg anod are the fast self-corrosion in an aqueous electrolyte and low anodic and cathodic kinetics along with few side reactions. One of the main reasons for those problems is the small variety of Mg alloys available today and the development that did not focus on applicability for MAB. Only applied research that will lead to a dedicated Mg alloy development could reduce the current application gap. This study will develop several low-cost Mg alloys and the relationship between alloying elements, process, and the Mg anode's discharge behavior will be studied. In addition, at the end of the development process, a prototype will be assembled for a Mg-Air battery taking into account the applicability of the battery in the near future and emphasizing applications in EVs.

יישומיות

פוטנציאל יישומי:

בעידן של פיתוח בר קיימא וחדשנות אקולוגית, צפיפות אנרגיה גבוהה היא אחת הדרישות הקריטיות לפיתוח אגירת אנרגיה חדשה, כולל פיתוח סוללות. טכנולוגיית סוללות מתכת-אוויר מוכרת בעולם שנים רבות ובמרכזה עומד העיקרון של הפקת אנרגיה ירוקה ממתכת המשתחררת באמצעות חימצון. כדי להבין את היישום של סוללות מתכת-אוויר לתחבורה צריך להבין איך עובדים רכבים חשמליים שכל האנרגיה שמניעה את הרכב מגיעה מסוללה ולכן אלה רכבים עם טווח המוגבל התלוי בסוללה בלבד. לסוללות מתכת-אוויר צפיפות אנרגטית גבוה (פי 3-30) בהשוואה לסוללות ליתיום הקיימות קיום. בנוסף, היתרון המרכזי בשימוש עתידי בסוללות מגנזיום-אוויר, הינו התכונות של מתכת המגנזיום המאפשרת צפיפות אנרגיה גבוהה יחד עם מתכת ידידותית לסביבה, בעלות נמוכה ומשקל נמוך. כל אלה יביאו לפתרון המרכזי הנדרש כיום בתעשיית התחבורה, כמו כן בתעשיות אחרות, לקבלת אנרגיה ירוקה וזולה ללא פליטות. היישום המרכזי עבור סוללות מגנזיום-אוויר הינו תעשיית הרכב, אך יש לקחת בחשבון שהפיתוח יאפשר שימושים נוספים ורבים כספק אנרגיה בחירום במצב המתנה עבור בתי חולים, בתי ספר, אזורי אסון וכמובן ציוד צבאי רגיש. מתכת המגנזיום הינה מתכת בעלת תכונות משופרות עבור יישום עתידי לאנודת עבור סוללות מתכת אוויר, כמו כן מתכת זו הינה המתכת היחידה המופקת ומיוצרת במדינת ישראל, כך שיישום עתידי יכול להביא להשפעה נרחבת לכלכלה ולאנרגיה במדינת ישראל

פטנטים הנוגעים למחקר: לא

האם מעורב קנין רוחני של צד ג': לא

קשר לחברה מסחרית / תעשייתית: לא

חשיבות המחקר:

היישום המרכזי עבור סוללות מגנזיום-אוויר הינו תעשיית הרכב, אך יש לקחת בחשבון שהפיתוח יאפשר שימושים נוספים ורבים כספק אנרגיה ירוקה בחירום במצב המתנה עבור בתי חולים, בתי ספר, אזורי אסון וכמובן ציוד צבאי רגיש. מתכת המגנזיום הינה מתכת בעלת תכונות משופרות עבור יישום עתידי לאנודת עבור סוללות מתכת אוויר, כמו כן מתכת זו הינה המתכת היחידה המופקת ומיוצרת במדינת ישראל, כך שיישום עתידי יכול להביא להשפעה נרחבת לכלכלה ולאנרגיה במדינת ישראל.

האם המחקר כולל

מחקר בבני אדם: לא | מחקר בבעלי חיים: לא | מחקר בצמחים: לא

מחקר בבתי ספר: לא

אני מודע/ת כי עלי לוודא את תוקף הארכת האישורים ככל שידרשו לאורך כל תקופת המחקר: לא

האם במחקר צפוי להיעשות שימוש בתשתיות ארגונים בינלאומיים בהם ישראל חברה: לא

קבוצות המחקר

פרטי חוקר

סוג חוקר: מרכז פרויקט

שם: Dr Guy Yehuda Ben Hamu

מוסד: המכללה האקדמית להנדסה - סמי שמעון

טלפון נייד: 0547787911

מומחיות: הנדסת חומרים, התנהגות סביבתית, טכנולוגיות ייצור

דואר אלקטרוני: guy@sce.ac.il

אחוז זמן בפרויקט: 25

סוג חוקר: חוקר ראשי

שם: Prof Amir Eliezer

מוסד: המכללה האקדמית להנדסה - סמי שמעון

טלפון נייד:

מומחיות: הנדסת חומרים, קורוזיה

דואר אלקטרוני: amir.eliezer11@gmail.com

אחוז זמן בפרויקט: 25

צוות המחקר

קבוצה	פרטים
Dr Guy Yehuda Ben Hamu	**תפקיד במחקר:** סטודנט לתואר שני **שם:** Ms Student A Student A **מוסד:** המכללה האקדמית להנדסה - סמי שמעון **דואר אלקטרוני:** **מומחיות:** הנדסת חומרים, קורוזיה
Dr Guy Yehuda Ben Hamu	**תפקיד במחקר:** דוקטורנט **שם:** Mr Student B Student B **מוסד:** המכללה האקדמית להנדסה - סמי שמעון **דואר אלקטרוני:** **מומחיות:** הנדסת חומרים
Prof Amir Eliezer	**תפקיד במחקר:** מהנדס מעבדה **שם:** Mr lab technician lab technician **מוסד:** המכללה האקדמית להנדסה - סמי שמעון **דואר אלקטרוני:** **מומחיות:** הנדסת מכונות / חומרים

זמינות

איני מעורב בפרויקטים אחרים: לא

חוקר ראשי	שם המוסד הממן	נושא הפרויקט	אחוז הזמן בפרויקט	סכום
Dr Guy Yehuda Ben Hamu	SCE	Environmental degradation of AM-fabricated structural alloys	15	180,000

תקציב מבוקש

מס' שנים: 3 **סה"כ תקציב מבוקש:** 741,836 **מטבע:** ILS

שכר

קבוצה	שם חוקר	חודשים למימון	סכום לשנה 1	סכום לשנה 2	סכום לשנה 3	סה"כ סכום
Dr Guy Yehuda Ben Hamu	דוקטורנט	12	83,300	83,000	83,300	249,600
Salary requested for Ph.D students ho will perform a Ph.D study on the various aspects of this proposal will spend 100% of .their time doing research						
Dr Guy Yehuda Ben Hamu	סטודנט לתואר שני	12	60,000	60,000	0	120,000
Salary requested for the scholarship of MSc students ho will perform a master study on the various aspects of this proposal will spend 100% of .their time doing research						
Prof Amir Eliezer	מהנדס מעבדה	3	20,825	20,825	20,825	62,475
Lab technician salary is allocated for successful sample preparation and characterization						
סה"כ			**164,125**	**163,825**	**104,125**	**432,075**

ציוד קבוע

קבוצה	תאור הציוד	סכום לשנה 1	סכום לשנה 2	סכום לשנה 3	סה"כ סכום

מקורות עצמיים

קבוצה	סעיף תקציבי	סך מקורות עצמיים	מטבע	תאור הציוד

ציוד קבוע יעודי

קבוצה	תאור הציוד	סכום לשנה	סכום לשנה 2	סכום לשנה 3	סה"כ סכום מבוקש

מחשבים

קבוצה	תאור הציוד	סה"כ סכום מבוקש

מיחשוב ייעודי

קבוצה	תאור הציוד	סה"כ סכום מבוקש

ציוד אזיל

קבוצה	תאור הציוד	סכום לשנה 1	סכום לשנה 2	סכום לשנה 3	סה"כ סכום
Dr Guy Yehuda Ben Hamu	Chemicals, Materials & lab consumables	20,000	20,000	20,000	60,000
.Lab consumables are standard: chemicals, solvents, glassware, gasses					
Dr Guy Yehuda Ben Hamu	Consumables Equipment and Materials for SEM	10,000	10,000	10,000	30,000
.Consumables for SEM and specimen preparation (such as lapping disks etc')					
Prof Amir Eliezer	Consumables Equipment for electrochemical tests	20,000	20,000	20,000	60,000
.Consumables for electrochemical tests (Reference and platinum electrodes)					
סה"כ		**50,000**	**50,000**	**50,000**	**150,000**

שונות

קבוצה	תאור ההוצאה	תקציב עבור	סכום לשנה 1	סכום לשנה 2	סכום לשנה 3	סה"כ סכום
Dr Guy Yehuda Ben Hamu	Service Per hour charges	אחר	15,000	15,000	15,000	45,000
Per-hour charges are an important part of this project, and are to cover the use of characterization equipment - XRD, SEM, TEM						
Dr Guy Yehuda Ben Hamu	דוח היתכנות יישומי	דוח היתכנות ישומי	0	5,000	0	5,000
Report Submission at the end of the second year in accordance with the requirements in the call						
Dr Guy Yehuda Ben Hamu	יישוג והנגשת תוצרי המחקר	יישוג	0	0	1,000	1,000
accessible the research products to the general public						
Dr Guy Yehuda Ben Hamu	יום עיון	כנס	0	0	3,000	3,000
Organization of one day seminar						
Dr Guy Yehuda Ben Hamu	Publication in scientific journals	פרסומים	0	4,500	4,500	9,000
Publication charges in scientific journals (including editing and translation)						
סה"כ			**15,000**	**24,500**	**23,500**	**63,000**

סיכום תקציב

סה"כ תקציב מבוקש: 741,836 **מטבע:** ILS

סיכום תקציב

סעיף תקציבי	סכום מבוקש לשנה 1	סכום מבוקש לשנה 2	סכום מבוקש לשנה 3	סה"כ סכום מבוקש
שכר	164,125	163,825	104,125	432,075
ציוד אזיל	50,000	50,000	50,000	150,000
שונות	15,000	24,500	23,500	63,000
תקורה	34,369	35,749	26,644	96,761
דמי ניהול	0	0	0	0
סה"כ	**263,494**	**274,074**	**204,269**	**741,836**

סיכום תקציב לפי שנים ללא תקורה

קבוצה	סכום מבוקש לשנה 1	סכום מבוקש לשנה 2	סכום מבוקש לשנה 3	סה"כ סכום מבוקש
Dr Guy Yehuda Ben Hamu	188,300	197,500	136,800	522,600
Prof Amir Eliezer	40,825	40,825	40,825	122,475
סה"כ	**229,125**	**238,325**	**177,625**	**645,075**

סיכום תקציב לפי קבוצה

קבוצה	סה"כ שכר	סה"כ ציוד	סה"כ ציוד יעודי	סה"כ מחשבים	סה"כ מחשבים ייעודי	סה"כ ציוד אזיל	סה"כ שונות	תקורה	דמי ניהול	סה"כ תקורה וניהול
Dr Guy Yehuda Ben Hamu	369,600					90,000	63,000	78,390	0	600,990
Prof Amir Eliezer	62,475					60,000		18,371	0	140,846
סה"כ	**432,075**	**0**	**0**	**0**	**0**	**150,000**	**63,000**	**96,761**	**0**	**741,836**

מקורות נוספים

מענקים ותמיכות אחרות שנתקבלו למחקר המוצע

חוקר ראשי	מקור מימון	סכום	מטבע	ממשלתי	תיאור	ת. קבלת המימון	ת. סיום קבלת המימון

אין לי מקורות מימון נוספים: כן

הצהרות מניעת כפל מימון:

אני מצהיר כי הצעת מחקר זו הינה מקורית ולא הוגשה למימון לקרנות אחרות

סוקרים

סוקרים מומלצים

שם (באנגלית)	מוסד	מדינה	דואר אלקטרוני	הערות
Prof Bongsun You	Korea Institute of Machinery and Materials	קוריאה הדרומית	bsyou@kims.re.kr	
Prof Alex Volinsky	University of South Florida	ארה"ב	volinsky@usf.edu	
Prof Andrej Atrens	The University of Queensland	אוסטרליה	andrejs.atrens@uq.edu.au	
Prof Arslan KAYA	Muğla University of	טורקיה	aakaya@mu.edu.tr	
Dr Sviatlana Lamaka	Helmholtz-Zentrum HereonInstitute of Surface Science	גרמניה	Sviatlana.Lamaka@hereon.de	

סוקרים לא מומלצים

שם (באנגלית)	מוסד	מדינה	דואר אלקטרוני	הערות
Prof Yair Ein-Eli	הטכניון	ישראל	eineli@technion.ac.il	
Prof Noam Eliaz	אוניברסיטת תל אביב	ישראל	neliaz@tauex.tau.ac.il	

צרופות

סוג מסמך	תאור	חוקר	הצגה לסוקר
קורות חיים	**קורות חיים**	Dr Guy Yehuda Ben Hamu	כן
קורות חיים	**קורות חיים**	Prof Amir Eliezer	כן
תכנית המחקר-מלאה			כן
תכנית המחקר - קדם	**תוכנית המחקר**		כן

RESEARCH PRE-PROPOSAL

Title: **_ Development of Magnesium anode for Mg-Air Battery _**

Project coordinator: **Dr. Guy Ben Hamu**

1. Abstract

In an era of sustainable development and innovation ecosystem, a high-energy-density is one of the critical requirements for developing new energy storage, including battery technology. Research to date confirms that, Metal-Air Batteries (MABs) have an exceptionally high energy density, durability, and specific power compared to conventional batteries. In addition, they are environmentally friendly, low-cost, and lightweight. The Mg-air battery is one of the most attractive battery systems and presents high theoretical voltage and energy density. Mg has physical and electrochemical properties, is inexpensive, and is an attractive candidate for MABs applications. Despite many advantages of Mg alloys, there is a scientific/technological gap in using Mg alloys as an anode for MAB. The two main issues for Mg anod are the fast self-corrosion in an aqueous electrolyte and low anodic and cathodic kinetics along with few side reactions. One of the main reasons for those problems is the small variety of Mg alloys available today and the development that did not focus on applicability for MAB. Only applied research that will lead to a dedicated Mg alloy development could reduce the current application gap. This study will develop several low-cost Mg alloys and the relationship between alloying elements, process, and the Mg anode's discharge behavior will be studied. In addition, at the end of the development process, a prototype will be assembled for a Mg-Air battery taking into account the applicability of the battery in the near future and emphasizing applications in EVs.

2. Scientific background and state of the art

The uncertain prospect of further improvements in current battery technologies such as Li-ion batteries (LIBs) has given opportunities for MABs to expand into the Electric Vehicle (EV) and stationary power markets. For pure EVs, batteries need to achieve a practical, specific energy density of 1700 Wh/kg, which is the usable specific energy density of gasoline (theoretical specific energy density of the fuel is 13 kWh/kg, the energy conversion efficiency of the tank-to wheel of the fleet is only 12.6%), and a volumetric energy density of 417 Wh/L to achieve a driving range of 500 miles (125 kWh capacity is required for a maximum 300 L battery). However, current batteries such as LIBs based on intercalation chemistry can only provide a capacity of ~200 Wh/kg, and it is generally believed that further improvements to LIB technology can only increase energy densities by up to 30% and may reach 400 Wh/kg in the future. As a result, researchers are exploring other practical high energy density alternatives that cost less than $100/kWh for EVs. Here, the theoretical energy densities of MABs are much higher than those of LIBs and therefore are often advocated as a promising solution for next generation electrochemical energy storage systems in EV or grid energy storage applications if high utilization efficiency, capacity and rate performance can be realized. Despite this, MABs remain in initial research stages due to associated challenges involving metal anodes, air cathodes and electrolytes, and their potential has yet far from been fully identified. And different from other batteries, MABs can combine the design capabilities of conventional batteries with the design capabilities of fuel cells. In addition, MABs possess larger theoretical energy densities (~3–30 times) than LIBs in which only the active component of the anode is stored and the reactant (O_2) from the air cathode during discharge is extracted from air through a reduction reaction, meaning that the main weight factor dominating the specific energy density of MABs is the anode metal. As a result, MABs are considered to be promising candidates for large-scale energy storage applications such as in EVs. Phynergy (Israel) developed a mass-producible Al-air battery that can significantly extend the range of current EVs before recharge. Companies such as Eos Energy Storage (NYC, USA), Fluidic Energy (Scottsdale Arizona, USA) and Powair (Europe) are also involved in the testing of Zn-air batteries in grid energy storage systems in pilot plants and Tesla Motors

has filed eight patent applications involving the use of MAB packs (Zn, Al, Fe, Mg, Li or V) as range extenders for traditional LIB packs. In 2009, IBM further launched the "Battery500"program with the aim of developing Li-air batteries with an ambitious target of 500 miles (800 km) driving range. Mg-air batteries are also being actively developed to power EVs. Magnesium is the fifth most abundant element in the earth's crust with a content of 3% and the only metal produced in Israel. As a result, widely available and inexpensive Mg (about 5% of Li metal costs) is an attractive candidate anode material for MAB applications. Mg possesses high reaction activities and is non-toxic, biocompatible and environmentally friendly. In addition, the use of Mg encounters significantly less safety and processing issues as compared with Li if exposed to air. Furthermore, Mg has a large negative standard electrode potential (2.37 V vs. NHE), and the theoretical specific energy density for the reaction between Mg and O_2 (6.80 kWh/kg). Mg also possesses a specific capacity of 2205 Ah/kg, making it almost twice superior to Li in volumetric capacity (3833 Ah/L vs. 2062 Ah/L). This can impart Mg-air batteries a huge advantage in applications, especially for limited installation space such as mobile devices and EVs. Under this background, Mg-air batteries using neutral aqueous electrolytes such as NaCl solutions, which are non-aggressive, safe, environmentally friendly and exempt from the current issues bedeviling both alkaline and acidic electrolytes, deserve researchers' interest. Research to date confirms that the high theoretical cell voltage (2.77 V) is far beyond practical values which are typically below 1.2 V in conventional saline aqueous electrolytes. This can be ascribed to high levels of anodic and cathodic polarization and low Coulombic efficiencies during discharge, resulting mainly from the parasitic corrosion of Mg and the sluggish kinetics of cathodic oxygen reduction reaction (ORR). And because Mg^{+2} is stable under a pH below 11 while $Mg(OH)_2$ is stable under a pH above Mg can spontaneously convert to Mg ions in both neutral and acidic aqueous environments and these generated Mg ions can further react with water through electrochemical mechanisms to generate magnesium hydroxide and hydrogen. Specifically, Mg can spontaneously react with water as a parasitic reaction to form interfacial $Mg(OH)_2$ film on electrodes as well as hydrogen. This interfacial $Mg(OH)_2$ film can subsequently block electronic and ionic conduction and terminate the discharge process of corresponding batteries due to high interfacial impedance.

3. Research objectives and specific aims

The electrochemical behavior of Mg alloys depends on the alloying elements, grain size, distribution on second phases, and process history. Up to data, no Mg alloys have been developed for anodes in MABs. Therefore, there is a gap in the applicability of Mg alloys to the anode uses in a MEBs.

The proposal aims are two stages: Develop high-performance Mg based anodes for MABs application with consideration of alloying elements and manufacturing process (i.e casting, extrusion, and porous structure). Along with developing new MABs based on Mg anode with discharge properties meeting the requirements of the EVs industry.

4. A short description of the proposed research

This research proposed to focus on two stages to answer the proposal aims:

In the first stage will be a fundamental understanding of the development of high-performance Mg-based anodes for MABs application: effective alloying elements design strategies and their influence on electrode reactions and side reactions. A minimum of 4 alloys will be developed; the alloys will be produced by three different methods: casting, plastic deformation, and powder metallurgy. Each process will affect the microstructure- performance relation. The relation between process method, alloying elements, and discharge performance will be studied by electrochemical tests (open circuit potential, electrochemical impedance spectra and potentiodynamic polarization). The discharge behavior will be recorded using a self-designed Mg- air battery tests system. The microstructural changes will study by optical and electronic microscopy. At the end of the first stage, selecting one alloy with the best performance will be done.

The second stage will focus on the development of MABs based on selected Mg anode (from the first stage) with discharge properties meeting the requirements of the EVs industry. At the end of this stage, a prototype of Mg-air buttery will be presented, along with recommendations for mass production of the battery system.

5. Significance, innovation and potential benefits of the proposed research

Environmental issues have become a challenge for humans, which urges green and sustainable energy sources. Recent decades have witnessed delightful developments in clean energy approaches such as solar and wind. However, these energy sources usually require large immovable equipment and are not available as portable power sources. Metal-air batteries have attracted increasing attention due to their attractive features. The Mg-air battery is one of the most attractive battery systems. The Mg-air battery can serve as a standby emergency energy supplier for schools, hospitals, etc., and can power military equipment as well as EVs. The Mg-air battery also provides energy for out-door adventure and emergency rescue due to its simple structure. New applications of the Mg-air primary battery include powering transient implantable devices and electronic contact lenses. These developments indicate a promising future for this battery system. Despite many studies done in recent years on the subject, no comprehensive study has been conducted that includes the development of a unique Mg alloy for use as an anode in the MABs and consideration the industrial feasibility for future use of future use Mg-Air battery system for EVs.

6. Applicability

The results obtained from this study could, in the near future, yield the production capability of a commercial Mg-Air battery system based on new high-performance Mg-based anodes. As stated in the aims, at the end of the study, a prototype for the developed Mg-Air battery will be presented, along with recommendations for commercial production under the industrial requirement (for various applications – from personal mobile to EVs)

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RESEARCH PROPOSAL

Title: **_ Development of Magnesium anode for Mg-Air Battery _**

Project coordinator: **_ Dr. Guy Ben Hamu _**

1. Abstract

In an era of sustainable development and innovation ecosystem, a high energy density is one of the critical requirements for developing new energy storage, including battery technology. Research confirms that Metal-Air Batteries (MABs) have an exceptionally high energy density, durability, and specific power compared to conventional batteries. In addition, they are environmentally friendly, low-cost, and lightweight. The Mg-air battery is one of the most attractive battery systems and presents high theoretical voltage and energy density. Mg has physical and electrochemical properties, is inexpensive, and is an attractive candidate for MABs applications. Despite many advantages of Mg alloys, there is a scientific/technological gap in using Mg alloys as an anode for MAB. The two main issues for Mg anode are the fast self-corrosion in an aqueous electrolyte, low anodic and cathodic kinetics, and few side reactions. One of the main reasons for those problems is the small variety of Mg alloys available today and the development that did not focus on applicability for MAB. Only applied research that will lead to a dedicated Mg alloy development could reduce the current application gap. This study will develop several low-cost Mg alloys, and the relationship between alloying elements, process, and the Mg anode's discharge behavior will be studied. In addition, at the end of the development process, a prototype will be assembled for an Mg-Air battery taking into account the applicability of the battery in the near future and emphasizing applications in EVs.

2. Scientific background and state of the art

The uncertain prospect of further improvements in current battery technologies such as Li-ion batteries (LIBs) has given opportunities for metal-air batteries to expand into the electric vehicle and stationary power markets. For pure EVs, batteries need to achieve a practical, specific energy density of 1700 Wh/kg, which is the usable specific energy density of gasoline (theoretical specific energy density of the fuel is 13 kWh/kg, the energy conversion efficiency of tank-to wheel of fleet is only 12.6%), and a volumetric energy density of 417 Wh/L to achieve a driving range of 500 miles (125 kWh capacity is required for a maximum 300 L battery). However, current batteries such as LIBs based on intercalation chemistry can only provide a capacity of ~200 Wh/kg, and it is generally believed that further improvements to LIB technology can only increase energy densities by up to 30% and may reach 400 Wh/kg in the future. As a result, researchers are exploring other practical high energy density alternatives that cost less than $100/kWh for EVs. Here, the theoretical energy densities of MABs are much higher than those of LIBs and therefore are often advocated as a promising solution for next generation electrochemical energy storage systems in EV or grid energy storage applications if high utilization efficiency, capacity and rate performance can be realized. Despite this, MABs remain in initial research stages due to associated challenges involving metal anodes, air cathodes and electrolytes, and their potential has yet far from been fully identified. In general, MABs are open electrochemical systems that use metal anodes (Li, Na, Mg, Fe, Zn, Al, etc.), ambient air open cathodes and electrolytes (aqueous or non-aqueous electrolyte depending on the nature of the anode employed). And different from other batteries, MABs can combine the design capabilities of conventional batteries with the design capabilities of fuel cells. In addition, MABs possess larger theoretical energy densities (~3–30 times) than LIBs in which only the active component of the anode (metal) is stored and the reactant (O_2) from the air cathode during discharge is extracted from air through a reduction reaction, meaning that the main weight factor dominating the specific energy density of MABs is the anode metal. As a result, MABs are considered to be promising candidates for large-scale energy storage applications such as in EVs. Phynergy (Israel) developed a mass-producible Al-air battery that can significantly extend the range of current EVs before recharge. Companies such as Eos Energy Storage (NYC, USA), Fluidic Energy (Scottsdale Arizona, USA) and Powair (Europe) are also involved in the testing of Zn-air batteries in

grid energy storage systems in pilot plants and Tesla Motors has filed eight patent applications involving the use of MAB packs (Zn, Al, Fe, Mg, Li or V) as range extenders for traditional LIB packs. In 2009, IBM further launched the "Battery500"program with the aim of developing Li-air batteries with an ambitious target of 500 miles (800 km) driving range. Mg-air batteries are also being actively developed to power EVs [1-4].

Magnesium is the fifth most abundant element in the earth's crust with a content of 3%, as well as the only metal produced in Israel. As a result, widely available and inexpensive Mg (about 5% of Li metal costs) is an attractive candidate anode material for MAB applications. And despite being less well-known than Zn-air batteries, Mg possesses high reaction activities and is non-toxic, biocompatible and environmentally friendly. In addition, the use of Mg encounters significantly less safety and processing issues as compared with Li if exposed to air. Furthermore, Mg has a large negative standard electrode potential (2.37 V vs. NHE), and the theoretical specific energy density for the reaction between Mg and O_2 (6.80 kWh/kg) ranks second among all MABs, far exceeding that of Zn-air batteries. Mg also possesses a specific capacity of 2205 Ah/kg, making it almost twice superior to Li in volumetric capacity (3833 Ah/L vs. 2062 Ah/L). This can impart Mg-air batteries a huge advantage in applications, especially for cases with limited in installation space such as mobile devices and EVs. Currently, Mg-air batteries have mainly been used in small, lightweight consumer-friendly portable power systems up to 100 W, although power is generally limited up to 5 kW, with important markets including small-sized devices such as emergency lanterns and emergency power backup systems for hospitals and schools as well as subsea instruments such as lighthouses, monitoring equipment and buoys. Under this background, Mg-air batteries using neutral aqueous electrolytes such as NaCl solutions, which are non-aggressive, safe, environmentally friendly and exempt from the current issues bedeviling both alkaline and acidic electrolytes, deserve researchers' interest. Furthermore, with the rapid growth of EVs and grid-scale energy storage systems, significant opportunities have arisen for primary Mg-air batteries, and have highlighted the importance of realizing in practice high rates and capacities in neutral electrolytes [1-2]. Primary Mg-air battery systems involve the electrochemical coupling of Mg anodes to air diffusion cathodes through suitable electrolytes to provide high-performance batteries with inexhaustible cathode reactants from atmospheric oxygen. During discharge, the Mg anode is oxidized to generate Mg^{+2} and two electrons whereas atmospheric oxygen reacts with water through the air diffusion cathode and is reduced to generate OH^- through electrochemical reactions, resulting in the outflow of electrons via an external circuit. The high theoretical cell voltage (2.77 V) is far beyond practical values which are normally below 1.2 V in conventional saline aqueous electrolytes. This can be ascribed to high levels of anodic and cathodic polarization and low Coulombic efficiencies during discharge, resulting mainly from the parasitic corrosion of Mg and the sluggish kinetics of cathodic oxygen reduction reaction (ORR). And because Mg^{+2} is stable under a pH below 11 while $Mg(OH)_2$ is stable under a pH above Mg can spontaneously convert to Mg ions in both neutral and acidic aqueous environments and these generated Mg ions can further react with water through electrochemical mechanisms to generate magnesium hydroxide and hydrogen. Specifically, Mg can spontaneously react with water as a parasitic reaction to form interfacial $Mg(OH)_2$ film on electrodes as well as hydrogen. This interfacial $Mg(OH)_2$ film can subsequently block electronic and ionic conduction and terminate the discharge process of corresponding batteries due to high interfacial impedance [4].

The Mg-air battery produces electricity through an electrochemical reaction in an aqueous electrolyte of the Mg alloy and the oxygen in the air. Mg-based anodes suffer from self-corrosion due to the anodic hydrogen reaction, also known as the Negative Difference Effect. The chemical step produces no electrons for the Mg-air battery, leading to poor anodic efficiency and poor discharge capacity. The chunk effect, the wasteful spalling of the metallic Mg chunks from the Mg anode during the discharge, is another self-corrosion mechanism that can significantly contribute to the loss in the utilization efficiency of Mg anode [5].

Three main approaches are usually adopted to cope with such practical limitations, namely anode material modification [6-26], anode material processing [27-40] and electrolyte chemistry modification [41-52]. The anode material modification via alloying of a wide range of elements and their combinations to the Mg anode has been extensively investigated in recent

years. Moreover, production processes, such as heat treatment and mechanical-deformation-based methods, have been utilized to investigate the effect of microstructural characteristics of different Mg anodes on their discharge performance. Improvement in the delivered voltage by any anode modification approach has usually been attributed to the easier detachment of the corrosion products during the discharge, which prevents the accumulative fouling of the Mg anode surface. Such characteristics are claimed to be induced by different microstructural features such as small and uniformly distributed second phases, long-period stacking order and the presence of twins. On the other hand, the reduction in the self-corrosion rate of the Mg anode during the discharge via anode modification approach has commonly been deduced from the lower corrosion rate of the developed Mg anode at open circuit potential (OCP), overlooking the polarization-dependent NDE. The extent of the chunk effect also strongly depends on the microstructure of the Mg anode, which, in turn, stems from the uneven dissolution of the Mg anode, especially along the grain boundaries and the secondary phases.

Despite many studies done on this topic, no scientific breakthrough has yet been reported for understanding and controlling the phenomenon. All this is due to the fact that the process of selecting the alloying elements together with the production method was not directly adapted to battery development but as part of a comprehensive study of the corrosion of magnesium alloys.

Although the auspicious results reported the significant effect of the electrolyte chemistry modification on the discharge performance of the primary Mg-air battery, relatively limited studies have explored this approach so far. An intuitive way of improving the utilization efficiency of the Mg-air battery via electrolyte modification is to add chemicals to the electrolyte with the already known corrosion inhibitive effect for the Mg anode.

The few recently published works based on the same approach of activating the Mg anode have introduced more effective complexing agents. They investigated different involved parameters, such as applied current density, the concentration of complexing agents, as well as combination of complexing agents with other electrolyte additives. Using the complexing agents and their mixtures as the electrolyte additive for primary Mg-air batteries is indeed revolutionary in terms of achieving the theoretical capacity and voltage of the batteries. However, the understanding of the enhancement mechanism, which may differ for different complexing agents, is at its nascent stage. However, most of the research work on this topic has been researched on Mg alloys that are not suitable for Mg-Air batteries applications.

Aside from anodic corrosion, the low Coulombic efficiency of Mg-air batteries is also caused by the slow kinetics of ORR. As a complex process in Mg-air batteries, ORR involves the diffusion of atmospheric oxygen to catalyst surface, the absorption of oxygen on catalyst surface, the transfer of electrons from anode to oxygen molecules, the breakage of oxygen bonds, and the removal of products from catalyst surface to electrolyte. Here, the reaction mechanism depends on pH environments, and to facilitate ORR, protons or hydroxyls are necessary (i.e. an acidic or alkaline environments). And neutral media (pH = 7) has been reported to have negative influence on ORR kinetics under high overpotentials due to lower proton and hydroxyl concentrations (10–7 mol/L) [4].

<u>**To date, no studies have been conducted that take into account the full perspective of the development Mg-Air batteries: from a selection of alloying elements along with the production processes method, anode geometry (solid or porous), and electrolyte chemistry modification with a view to the application.**</u>

3. Research objectives and specific aims

The electrochemical behavior of Mg alloys depends on the alloying elements, grain size, distribution on second phases, and process history. Up to data, no Mg alloys have been developed for anodes in MABs. Therefore, there is a gap in the applicability of Mg alloys to the anode uses in a MEBs.

The proposal aims are two stages: Develop high-performance Mg based anodes for MABs application with consideration of alloying elements and manufacturing process (i.e casting, extrusion, and porous structure). Along with developing new MABs based on Mg anode with discharge properties meeting the requirements of the EVs industry.

4. Detailed description of the proposed research

This research proposed to focus on two stages to answer the proposal aims:

In the first stage will be a fundamental understanding of the development of high-performance Mg-based anodes for MABs application: effective alloying elements design strategies and their influence on electrode reactions and side reactions. A minimum of 4 alloys will be developed; the alloys will be produced by three different methods: casting, plastic deformation, and powder metallurgy. Each process will affect the microstructure- performance relation. The relation between process method, alloying elements, and discharge performance will be studied by electrochemical tests (open circuit potential, electrochemical impedance spectra and potentiodynamic polarization). The discharge behavior will be recorded using a self-designed Mg- air battery tests system. The microstructural changes will study by optical and electronic microscopy. At the end of the first stage, selecting one alloy with the best performance will be done.

The second stage will focus on the development of MABs based on selected Mg anode (from the first stage) with discharge properties meeting the requirements of the EVs industry. At the end of this stage, a prototype of Mg-air battery will be presented, along with recommendations for mass production of the battery system.

5. Significance, innovation and potential benefits of the proposed research

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6. Applicability

The results obtained from this study could, in the near future, yield the production capability of a commercial Mg-Air battery system based on new high-performance Mg-based anodes. As stated in the aims, at the end of the study, a prototype for the developed Mg-Air battery will be presented, along with recommendations for commercial production under the industrial requirement (for various applications – from personal mobile to EVs)

7. Work plan and Gantt

#	Task	1-3	4-6	7-9	10-12	13-15	16-18	19-21	21-24	25-30	31-36
1	**Preparation of raw material**: new Mg alloys (alloying with different elements)	X									
2	**Production the Mg anodes**: Three different processes (casting, extrusion and porous structure)	X	X	X							
3	**Characterization the microstructure of the Mg-anodes**: Optical and electronic microscopy, XRD.		X	X	X						
4	**Characterization of the electrochemical behavior of the Mg-anodes**: Electrochemical test – AC and DC polarization, hydrogen evaluation test, surface morphologies		X	X	X	X					

5	**Characterization the discharge performance of Mg-anodes**				X	X	X				
6	**Selecting the optimal performing alloy for the required application**							X			
7	**Design and manufacturing of one battery cell**: Cathode selection, anode geometry, solution volume and distance between battery components							X	X		
8	**Effect of electrolyte additives on anode response and battery performance**									X	
9	**Design manufacturing and optimization of Mg-Air battery prototype – stack cells battery**										X

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41. **S. Fajardo, G.S. Frankel, Effect of impurities on the enhanced catalytic activity for hydrogen evolution in high purity magnesium, Electrochim. Acta 165 (2015) 255–267**
42. **F.W. Richey, B.D. McCloskey, A.C. Luntz, Mg anode corrosion in aqueous electrolytes and implications for Mg-air batteries, J. Electrochem. Soc. 163 (2016) A958–A963,**
43. **M.A. Deyab, Decyl glucoside as a corrosion inhibitor for magnesium-air battery, J. Power Sources 325 (2016) 98–103**
44. **Y.C. Zhao, G.S. Huang, G.L. Gong, T.Z. Han, D.B. Xia, F.S. Pan, Improving the intermittent discharge performance of Mg-air battery by using oxyanion corrosion inhibitor as electrolyte additive, Acta. Metall. Sin.-Engl. 29 (2016) 1019–1024**
45. **Y. Zhao, G. Huang, C. Zhang, C. Peng, F. Pan, Effect of phosphate and vanadate as electrolyte additives on the performance of Mg-air batteries, Mater. Chem. Phys. 218 (2018) 256–261**
46. **D. Hoche, S.V. Lamaka, B. Vaghefinazari, T. Braun, R.P. Petrauskas, M. Fichtner, M.L. Zheludkevich, Performance boost for primary magnesium cells using iron complexing agents as electrolyte additives, Sci. Rep. 8 (2018) 7578,**
47. **L. Wang, D. Snihirova, M. Deng, B. Vaghefinazari, S.V. Lamaka, D. H¨oche, M. L. Zheludkevich, Tailoring electrolyte additives for controlled Mg-Ca anode activity in aqueous Mg-air batteries, J. Power Sources 460 (2020) 228106**
48. **D. Snihirova, L. Wang, S.V. Lamaka, C. Wang, M. Deng, B. Vaghefinazari, D. Hoche, M.L. Zheludkevich, Synergistic mixture of electrolyte additives: a route to a high-efficiency Mg-air battery, J. Phys. Chem. Lett. 11 (2020) 8790–8798**
49. **L.Q. Wang, D. Snihirova, M. Deng, C. Wang, D. Hoche, S.V. Lamaka, M. L. Zheludkevich, Indium chloride as an electrolyte additive for primary aqueous Mg batteries, Electrochim. Acta 373 (2021) 137916**
50. **Y.X. Zhou, X.P. Lu, L. Yang, D. Tie, T. Zhang, F.H. Wang, Regulating discharge performance of Mg anode in primary Mg-air battery by complexing agents, Electrochim. Acta 370 (2021) 137805**
51. ***B. Vaghefinazari, D. Hoche, S.V. Lamaka, D. Snihirova, M.L. Zheludkevich, Tailoring the Mg-air primary battery performance using strong complexing agents as electrolyte additives, J. Power Sources 453 (2020) 227880**

52. *B. Vaghefinazari, , D. Snihirova, C. Wang, L. Wang, M. Deng, D. Hoche, S. Lamaka, M. Zheludkevich, Exploring the effect of sodium salt of Ethylenediaminetetraacetic acid as an electrolyte additive on electrochemical behavior of a commercially pure Mg in primary Mg-air batteries, Journal of Power Sources 527 (2022) 231176

Principal Investigator: BEN HAMU, GUY, Yehuda

BIOGRAPHICAL SUMMARY

NAME	POSITION TITLE
GUY Yehuda BEN HAMU	Senior lecturer Head, Department of Mechanical Engineering – Ashdod Campus (SCE) Head, Advanced Manufacturing & Surface Analysis Lab

EDUCATION/TRAINING

INSTITUTION AND LOCATION	DEGREE (*if applicable*)	MM/YY	FIELD OF STUDY
Ben Gurion University of the Negev, Israel.	B.Sc	09/00	Materials Engineering
Ben Gurion University of the Negev, Israel. Materials Engineering	M.Sc	02/03	Corrosion and Electrochemistry of Mg alloys
Ben Gurion University of the Negev, Israel. Materials Engineering	Ph.D	09/08	Corrosion and stress corrosion cracking of New Wrought magnesium alloys
Ben Gurion University of the Negev, Israel.	Post - Doc	09/09	Hydrogen interaction with structural materials

A. Personal Statement

My research work is focused in Materials Engineering – physical metallurgy of Magnesium alloys and corrosion behavior of magnesium alloys as a field of knowledge, and the investigation of physical-chemical phenomena related to interaction of corrosion environment with different magnesium alloys following thermo-mechanical history. On the basis of my scientific achievement, I was awarded a grant, from the German-Israeli Foundation for Scientific Research and Development – GIF young scientists program during 2013.

Due to my extensive research activity, in 2015 I set up my research lab in Ashdod Campus – Advanced Manufacturing & Surface Analysis Lab – that contains all the equipment required to run my research and enabling graduate students to conduct their research. Until now, 8 M.Sc. students from different engineering Department, and one Ph.D. student work in my Lab.

B. Positions and Honors

Since 2013 Senior Lecturer,
Head, Mechanical Engineering Department – Ashdod Campus,
SCE - Sami Shamoon College of Engineering, Beer Sheva & Ashdod Campus, Israel.

C. Selected Peer-reviewed Publication.

1. *Y. Templeman, G. Ben-Hamu, L. Meshi, "Friction stir welded AM50 and AZ31 Mg alloys: Microstructural evolution and improved corrosion resistance", *Materials characterization*, 126, (2017), 86-95. [26, I.F=3.562, Q1]

2. G. Ben-Hamu, D. Shamir, M. Zohar, A. Burg, "Acceleration of the corrosion reaction of magnesium by Fenton reagents ", *Journal of Coordination Chemistry*, 77, 11-13, (2018), 1852-1862. [1(1), I.F=1.41, Q3]

3. *P. Metalnikov, G. Ben-Hamu, Y. Templeman, K.S. Shin, L. Meshi, "The relation Between Mn Additions, Microstructure and Corrosion Behavior of New Wrought Mg-5Al alloys", *Materials Characterization*, 145, (2018), 101–115. [17(2), I.F=3.562, Q1]
4. G. Ben-Hamu, P. Metalnikov, D. Eliezer, K.S. Shin "Corrosion Mechanisms of new Wrought Mg-Al based alloys Alloying with Mn, Zn and Sn", *Materials Science Forum*, 941, (2018), 1880-1885. [_, I.F=0.35, Q3]
5. *P. Metalnikov, G. Ben-Hamu, D. Eliezer, K.S. Shin, "Role of Sn in microstructure and Corrosion Behavior of new Wrought Mg-5Al alloy" *Journal of Alloys and Compounds*, 777, (2019), 835-849. [15(1), I.F=4.65, Q1]
6. M. Zohar, D. Shamir, G. Ben-Hamu and A. Burg, "Innovative, DPN-Based Method for Analyzing the Early Stages of Mg Corrosion Under Natural Conditions", *Metals and Materials International*, (2019), 1-7. [_, I.F=1.99, Q1]
7. *P. Metalnikov , G. Ben-Hamu, K.S. Shin, "Relation Between Zn Additions, Microstructure and Corrosion Behavior of New Wrought Mg-5Al Alloys", *Metals and Materials International*, (2019), 1-13. [2, I.F=1.99, Q1]
8. G. Ben-Hamu and P. Metalnikov, "Development of New Wrought Mg Alloys: Improving the Corrosion Resistance by Addition of Alloying Elements", *Diffusion Foundations*, 27, (2020), 50-60. [_, I.F=0.66, Q1]
9. P. Metalnikov, D. Eliezer, G. Ben-Hamu, E. Tal-Gutelmacher, C. Munteanu, "Hydrogen embrittlement of electron beam melted Ti–6Al–4V", *Journal of Materials Research and Technology*, 9 (6), (2020), 16126-16134. [9(1), I.F=5.29, Q1]
10. P. Metalnikov, D. Eliezer, G. Ben-Hamu, "Hydrogen Trapping in Additive Manufactured Ti-6Al-4V Alloy",*Materials Science and Engineering A*, 811, (2021), 141050 [2, I.F=4.65, Q1]
11. *P. Metalnikov , G. Ben-Hamu, K.S. Shin, A. Eliezer " Effect of Ca Addition on Corrosion Behavior of Wrought AM60 Magnesium Alloy in Alkaline Solutions", *Metals*, (2021), 1172. [1, I.F=2.351, Q1]

D. Research Support

Topic	Funded by/ Amount	Year
Effect of the welding parameters on microstructure, mechanical properties and corrosion behavior of dissimilar FSWed joints in aluminum and magnesium alloys sheets	SCE Research Grant,	10/2012 – 9/2013
Corrosion Behavior and Local Potential Measurements with the Scanning Kelvin Probe Force Microscopy	German-Israeli Foundation for scientific research and Development – GIF young scientists program	2013
Experimental study of patient-specific orthopedic implants manufactured by Additive Manufacturing	SCE Research Grant,	10/2015 – 9/2018
Implants base Nitinol	OCON Medical Ltd.	2016
Hydrogen trapping and hydrogen storage of New Mg alloys	SCE Excellent Research Grant,	10/2018 – 9/2021
Hydrogen evaluation rate of salt sludge powders	ICL Group Ltd.	9-12/2020
Characterization of Structural Materials	IDF-IAF	1-12/2021
Engine Project - Materials selection and design for manufacturing	Aeronautics Ltd.	4/2021 – 12/2022
Environmental degradation of AM-fabricated structural alloys	SCE Excellent Research Grant,	10/2021 – 9/2024

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Principal Investigator (Last, First, Middle):

BIOGRAPHICAL SUMMARY

NAME	POSITION TITLE
Amir Eliezer	Prof. Department of Mechanical Engineering -SCE Director-Corrosion Research Center

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	MM/YY	FIELD OF STUDY
Ben-Gurion University of the Negev	B.Sc	09/1995	Materials Engineering
Ben-Gurion University of the Negev	M.Sc	09/1997	Materials Engineering
Ben-Gurion University of the Negev	M.B.A	10/2001	Business Administration
Ben Gurion University of the Negev	Ph.D	10/2002	Materials Engineering

A. Personal Statement *(Briefly describe how your experience and qualifies you to undertake the role assigned (e.g., PI, researcher, etc.) in the project proposed in the current application).* **Since 2003 my research is focused on magnesium alloys, electrochemistry and corrosion. Since 2004 I'm acting as the Director of the corrosion research center once degradation of magnesium alloys is strongly studied. The current application will focus on battery cells based on the magnesium reaction which is also the basic of my previous work on surface treatments, coatings, in-situ corrosion cells once all of the above will lead our proposed project to high success rate. My background on magnesium alloys manufacturing and development based on corrosion parameters will lead us to define the highest performance for such a magnesium battery. The corrosion center has all the required corrosion facilities to perform the proposed study.**

B. Positions and Honors *(List in chronological order previous positions, concluding with the present position. List any honors)*

Positions
June/2011- October 2017 Dean The Authority for Research & Development –SCE
June/2011- October 2017 Director , Entrepreneurship & Innovation Center-SCE
Since April/2004 Director, Corrosion Research Center, Nano-Bio & Advanced Materials.-SCE

AMPP -The Association for Materials Protection and Performance
AMPP Board of Directors Vice Chair 2022
AMPP Board of Directors 2020-2021

NACE INTERNATIONAL
European Area Director, 2018-2020
Chair, 2015 -2018
Vice Chair, 2012 -2015
Secretary, 2011- 2012
Treasurer, 2011- 2012
Editor, Corrodia, 2009-2011
Board member at large, 2006-2011

Principal Investigator (Last, First, Middle):

World Corrosion Organization NGO , UN and others
Since 2016- Past President WCO
2013-2016 President WCO

Honors
2018 SRB Excellence Award BioMedD 2018
2013 H.H. Uhlig Award NACE International
2006 General Motors Foundation GM-UMIT Recognition Award
2005 General Motors Foundation GM-UMIT Recognition Award
2003 General Motors Foundation GM-UMIT Recognition Award
2000-2002 Daniel Falkner Foundation, England,

C. Selected Peer-reviewed Publications *(List selected peer-reviewed publications or manuscripts in press. Mark the 5 most relevant articles for the research proposal)*1. P.L. Bonora, M. Andrei, A. Eliezer, E. M. Gutman: DC and AC polarisation study on Magnesium alloys; Influence of the mechanical deformation. *Materials and Corrosion,* 53, no. 7 (2002) 462-470

2. R.M. Wang, A. Eliezer, E. M. Gutman: Microstructures and dislocations in the stressed AZ91D magnesium alloys*. Materials Science and Engineering A* 344(2002) 279-287

M.Schorr, N. Lotan, Benjamin Valdez, A. Eliezer, Monica Carrillo,"Metals corrosion and biological respiration: similarities and disparities. An Overview. Journal of Materials Education, Vol. 33, Nos. 3-4, Pages 133-140 (2011).

4. C. Gasqueres, G. Schneider, R. Nusko, G. Maier, E. Dingeldein, A. Eliezer,
" Innovative antibacterial coating by anodic spark deposition", Journal of Surface & Coatings Technology, 206 (2012) , 3410-3414

5. P.Molnikov, G. Ben-Hamu, K.S. Shin, A. Eliezer, “Effect of Ca Addition on Corrosion Behavior of Wrought AM60 Magnesium Alloy in Alkaline Solutions ”Metals 2021 11(8), Special Issue Corrosion Behavior of Magnesium Alloys July 2021

D. Research Support *(List selected ongoing and completed research projects in the past three years in order of relevance to the research proposed in the application)*

Ongoing research

1. Surface protection methods for biomaterials medical devices
2. Corrosion behavior of pipelines and protection

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