THE EFFECT OF DIFFERENT MATERIALS ON PLASMA GENERATION AT ATMOSPHERIC PRESSURE

SABRINA BINTI ISMAIL

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

THE EFFECT OF DIFFERENT MATERIALS ON PLASMA GENERATION AT ATMOSPHERIC PRESSURE

SABRINA BINTI ISMAIL

A report submitted
in fulfillment of requirements for degree of
Bachelor of Mechanical Engineering with Honours

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

DECLARATION

I declare that this project report entitled "The Effect of Different Materials on Plasma Generation at Atmospheric Pressure' is the result of my own work except as cited in the references.

Signature : ....

Name : ....

Date : ....

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for award of the degree of Bachelor of Mechanical Engineering with Honours.

Signature : ....

Supervisor's Name : ....

Date : ....

DEDICATION

To my beloved mother and father.

ABSTRACT

Plasma is the fourth state of matter created after gas when energy is continuously supplied to neutral gas and charge carriers form. Fluorescent light and aurora are the other plasma in nature that available in vacuum space. However, the process for plasma discharge is difficult and considered expensive, also the entire process is carried out under low pressure conditions (Non-Thermal Equilibrium Plasma). Thus, a 2.45 GHz domestic microwave oven was used in this study to generate plasma in air at atmospheric pressure (Thermal Equilibrium Plasma). Copper (*Cu*) electrode samples of 30 mm, 60 mm, 120 mm, and 180 mm in length were prepared to determine the ideal length of electrode for plasma discharge with power output modes of 55% (medium), 77% (medium-high), and 100% (medium). Afterwards, Aluminium (*Al*), Zinc (*Zn*), Lead (*Pb*), Iron (*Fe*), and Brass were used to evaluate and compare the ability of each electrode on plasma generation at atmospheric pressure. Plasma generation was observed at the electrode tip in air at atmospheric pressure. According to the studies, in terms of the time taken to discharge plasma, the power consumption, and the thermal conductivity of material, the finding concludes that Copper (*Cu*) is the most suitable material for plasma generation followed by Brass, Aluminium (*Al*), Iron (*Fe*), Zinc (*Zn*) and Lead (*Pb*) also the ideal length of the electrode on plasma generation is 60 mm with using medium-high power mode.

ABSTRAK

Plasma merupakan keadaan yang keempat dari keadaan jirim yang dihasilkan selepas gas yang tercipta apabila tenaga secara berterusan dibekalkan kepada gas neutral dan membentuk cas pembawa. Cahaya floresen dan aurora adalah plasma lain yang terdapat di ruang vakum. Namun, proses penjanaan plasma sukar dan dianggap mahal, juga keseluruhan proses dilakukan dalam keadaan tekanan rendah (Plasma Keseimbangan Bukan Termal). Oleh itu, ketuhar gelombang mikro domestik 2.45 GHz digunakan dalam kajian ini untuk menghasilkan plasma di udara pada tekanan atmosfera (Plasma Keseimbangan Termal). Sampel elektrod kuprum dengan panjang 30 mm, 60 mm, 120 mm, dan 180 mm disediakan untuk menentukan panjang elektrod ideal untuk pelepasan plasma dengan mod kuasa output 55% (sederhana), 77% (sederhana tinggi), dan 100% (sederhana). Selepas itu, Aluminium (Al), Zink (Zn), Besi (Fe), Timah (Pb), dan Tembaga digunakan untuk menilai dan membandingkan kemampuan setiap elektrod pada penghasilan plasma pada tekanan atmosfera. Penjanaan plasma diperhatikan pada hujung elektrod di udara pada tekanan atmosfera. Menurut kajian, dari segi masa yang diperlukan untuk membuang plasma, penggunaan tenaga, dan kekonduksian terma bahan, penemuan ini menyimpulkan bahawa Kuprum (Cu) adalah bahan yang paling sesuai untuk penjanaan plasma diikuti dengan Tembaga, Aluminium, Besi, Zink dan Timah sehubungan itu panjang elektrod yang ideal pada penghasilan plasma adalah 60 mm dengan menggunakan mod kuasa tinggi sederhana.

ACKNOWLEDGEMENT

In the name of Allah, the Most Gracious and the Most Merciful for giving me strength and health to carry out my study and complete my final year project (FYP).

Next, I would like to take this opportunity to express my sincere acknowledgement to my supervisor Dr Fadhli bin Syahrial for his essential supervision, support, and encouragement towards the completion of this project. Throughout the period, he provides me a lot of knowledge not only in this project but also other useful knowledge.

Particularly, I would like to express my deepest gratitude to Mr Azhar, who always guide me handling the experiments also give ideas how to improve the procedure to get better result. I also want to thank my research partner, Nurul Hasni binti Kamaruddin who help me during this project.

Special thanks to all my peers, my beloved mother and father and my siblings for their moral support in completing my degree. Lastly, thank you for those who had taken part in realization of this project.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

DBD	Dieletctric Barrier Discharges
CD	Corona Discharge
PAW	Plasma Arc Welding
TIG	Tungsten inert gas
GTA	Gas Tungsten Arc
CNC	Computer Numerical Control

LIST OF SYMBOLS

Cu	=	Copper
Al	=	Aluminium
Zn	=	Zinc
Pb	=	Lead
Fe	=	Iron
℃	=	Degree celcius
GHz	=	Gigahertz
T_i	=	Ion temperature
T_e	=	Electron temperature
T_p	=	Plasma temperature
Ts	=	Surface temperature
T_b	=	Bulk temperature
λ	=	Wavelength
c	=	Speed of light , $2.99792 \times 10^8\ ms^{-1}$
f	=	Frequency
ε_r	=	Relative permittivity of the medium
CO_2	=	Carbon dioxide
kWh	=	Kilowatt hour
S	=	Second

J/kg.K	=	Joule per kilogram kelvin
W/m.K	=	Watt per meter kelvin
Cal/kg.K	=	Calorie per kilogram kelvin
C_p	=	Constant pressure heat capacity
C_v	=	Constant volume heat capacity
Q	=	Heat transfer through material
A	=	Area
T_1	=	Hot temperature
T_2	=	Cold temperature

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Solid, liquid, and gas are the fundamental states of matter that are commonly known. In the 1920s, chemist Irving Langmuir [1] was officially named another matter which is plasma (the fourth state of matter). Plasma is an ionized gas made up of ion gas atoms that are subjected to heat and removed some of the orbital electrons and free electrons. Next, plasma has a vast number of applications in engineering systems, including medical systems used in industries such as cancer treatment and sterilization [2]. Meanwhile, plasma is being used in the engineering industry for wastewater treatment [3] and metal cutting [4].

In this globalization era, many engineering industrial and medical industrial took advantage of using plasma as industrial usage to develop the product for their daily use. The advantage of using plasma in the medical-industrial can be microbial life kill, including incredibly immune bacterial endospores, eradicate selective tumor cells, and healing wounds [5]. However, the advantage of plasma in the engineering industry can improve the surface properties of inert materials [6] and be able to cut on conductive materials [7]. In recent years, due to the fast development of science and technology, various methods have been found by another researcher regarding plasma generation. One of the methods to generate plasma that has been found by another researcher is using a domestic microwave oven where the operating frequency is 2.45 GHz. It is because of the potential to produce extreme discharges in chemically active gases with low maintenance [8].

Most of the researches were on the electrode effects on plasma discharge using microwave irradiation at atmospheric pressure has been obtained to understand the concept of plasma generation [9]. However, these past studies were only focusing on a copper electrode. As such, the reviews on the effect of different material on plasma generation at atmospheric pressure is still less numerous. Therefore, this study will compare the effects of different materials of electrodes on plasma generation at atmospheric pressure where the electrode variation such as Copper (Cu), Aluminium (Al), Zinc (Zn), Lead (Pb), Iron (Fe), and Brass have experimented.

1.2 Problem Statement

Plasma is available in nature in vacuum space, for example, aurora, sun, and fluorescent light. However, it is difficult to discharge at atmospheric pressure. It is because low-pressure plasma has a limited gas temperature which is below 150℃, to avoid the thermally sensitive substrates from being damaged [10]. Besides, the cost for the vacuum system is more expensive and have high maintenance cost compared with generate plasma at atmospheric pressure. Nonetheless, it is difficult to discharge at atmospheric pressure due to the size limitation to be treated in the vacuum chamber [11]. Therefore, in this project, the task is to discharge plasma at atmospheric pressure.

1.3 Objective

The objectives of this project are as follows:

1. To generate plasma at atmospheric pressure by using microwave radiation.
2. To compare the effect of different materials of electrodes on plasma generation at atmospheric pressure.

1.4 Scope of Project

The scopes of this project are listed below:

1. The research will be conducted using a domestic microwave oven with a frequency of 2.45 GHz.
2. To determine the best length for plasma discharge, four Copper (*Cu*) electrode lengths are proposed: 30 mm, 60 mm, 120 mm, and 180 mm for plasma generation.
3. The microwave oven's power output varies between 55% (medium), 77% (medium-high), and 100% (high) of its maximum power of 700W, which is also used to generate plasma.
4. For plasma generation, six electrode materials are being analysed: Cooper (*Cu*), Aluminium (*Al*), Zinc (*Zn*), Lead (*Pb*), Iron *(Fe*), and Brass.
5. Finally, during the experiment, time taken and power consumed for plasma discharge are also evaluated for comparison of the effect of different materials on plasma generation at atmospheric pressure.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will discuss an overview of the effect of different materials of electrodes on plasma generation at atmospheric pressure. The fundamental knowledge of plasma generation and microwave plasma at atmospheric pressure will be elaborated on further in this chapter. Next, the microwave plasma at atmospheric pressure would be further interpreted regarding achieving the optimum length of the electrode. Lastly, the review of electrode configuration and thermal properties of the electrodes also will be elucidated further in this chapter.

2.2 Theory of Plasma

Plasma is recognized as the fourth state of matter where discovered by William Crooks in 1879 and 1928, Irving Langmuir officially named this state of matter as 'Plasma' [12]. Plasma is made up of ion gas atoms that are subjected to heat and removed some of the orbital electrons and free electrons, where plasma can be defined as an ionized gas as shown in **Figure 2.1**. Usually, plasma generation is produced by an electrical discharge. However, Plasma can be generated in various methods.

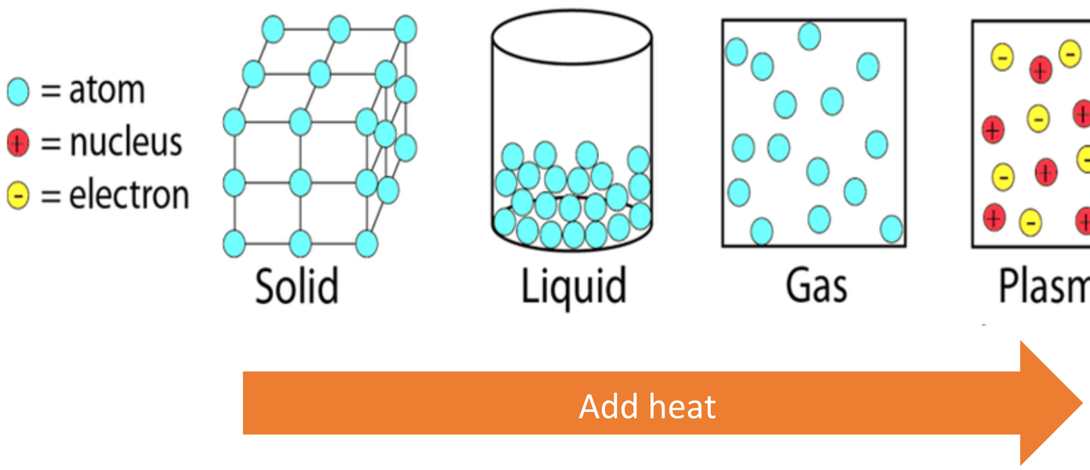

Figure 2.1: Transition of Matter [13]

Next, plasma has similar characteristics as gases such as no fixed shape or volume and less dense than solid and liquid [14]. However, both matters are completely different. It is because plasma is generated by supplying energy such as supply thermal energy or the high voltage of electricity to a neutral gas causing the formation of charge carriers as shown in **Figure 2.2**. Besides, with the sufficient energy of electrons or photons, it will collide with the neutral atoms and molecules in the feed gas where the impact known as electron impact ionization or photoionization [15].

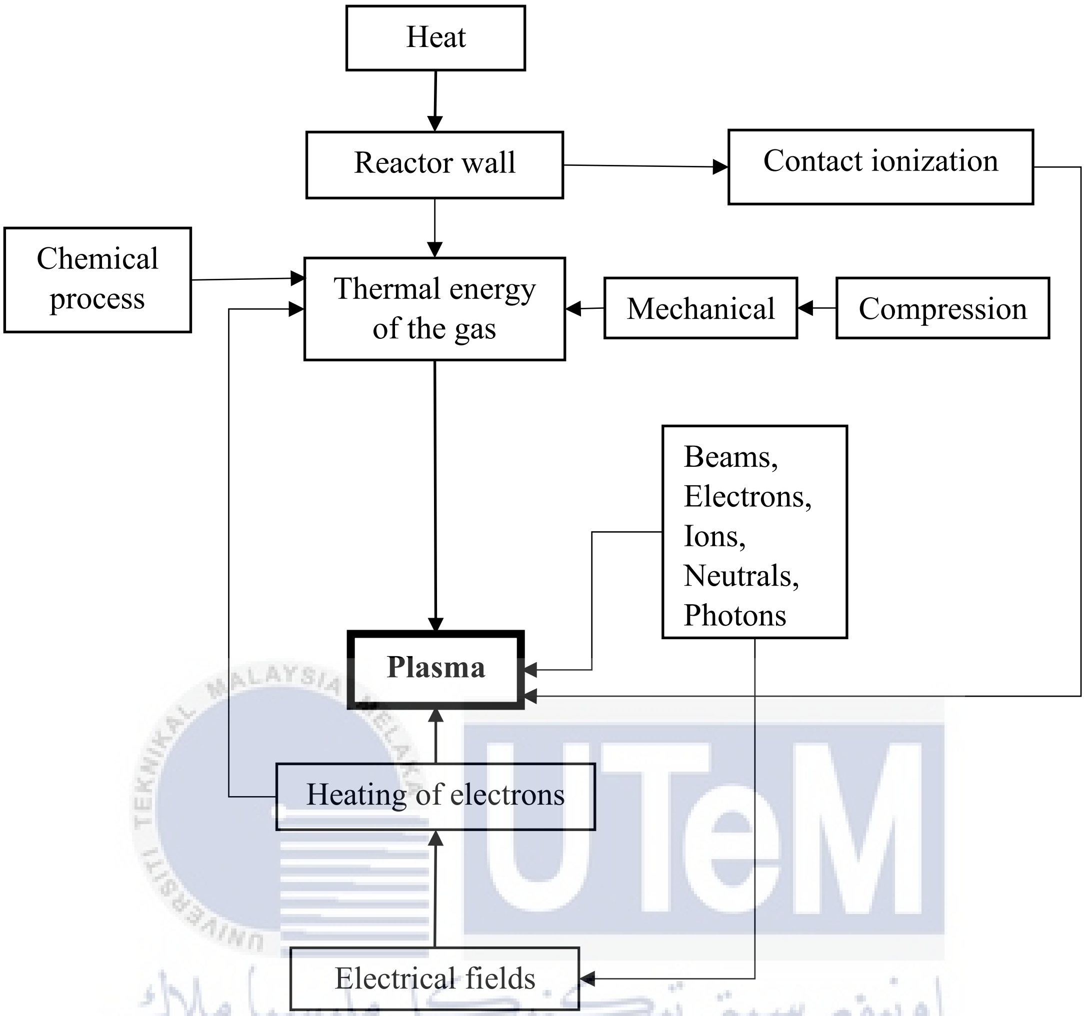

Figure 2.2: Principles of plasma generation [16]

Lastly, plasma is also presented in nature. Sun and stars are in a plasma state [17]. Plasma in Earth's magnetosphere sometimes flows along Earth's magnetic field to polar regions, creating the colourful light shows in the sky known as the Aurora or Southern and Northern Lights. These beautiful displays occur when energetic plasma particles collide with atmospheric gases and caused glow such as fluorescent and neon lights to shine [18].

2.3 Type of Plasma

The plasma generation process requires the application of energy to the gas, which causes the ionisation of gas [19]. Due to the temperature of the electrons, plasma is classified into two groups: (i) high-temperature plasma (thermal equilibrium plasma) and (ii) low-temperature plasma (non-thermal equilibrium plasma) based on the degree of ionisation, atmospheric pressure, and temperature [20].

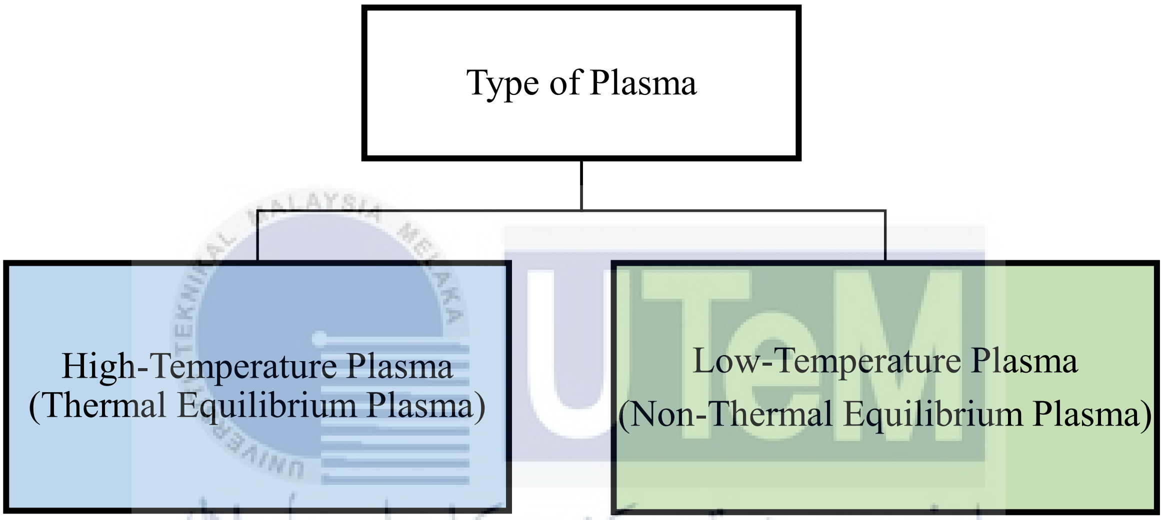

Figure 2.3: Type of Plasma

Two important parameters that can categorize high-temperature plasma (thermal equilibrium plasma) and low-temperature plasma (non-thermal equilibrium plasma) are ion temperature (T_i) and electron temperature (T_e) [21]. T_e represents the thermal acceleration of the electron. While T_i referred to the temperature of electrons, heavy particles, ions, and neutrals. Plasma temperature is also known as the average temperature of the centre of plasma, surface temperature and bulk temperature which is the average temperature of bulk material are considered to identify and differentiate the plasma because of modification of