Chapter 1

Introduction

1.1 Introduction

Plasmas are traditionally divided into two major categories, thermal and non-thermal. Thermal plasma requires high input energy to ionize the gas, and to establish thermal equilibrium among all the species (ions, electrons, gas atoms). Non-thermal plasma may be produced with lower input energy. In an electrical discharge, the electrical energy is first absorbed by the electrons and the heating of the atoms and ion is achieved through collisions. In a low current electrical discharge, the plasma is not in thermal equilibrium, the electrons are preferentially heated by the electric field (in some cases, by the magnetic field as well), while the neutral gas atoms and ions are at a relatively low temperature. Although the low temperature plasmas have been extensively studied, more work is needed to further enhance our understanding on these types of plasmas [1].

Glow discharge is one type of low temperature plasmas which are being used extensively in industry for various processes. In the glow discharge plasma, the gas is partially ionized and it is assumed to be consisting of nearly equal numbers of ions and electrons and a larger number of neutral species. The discharge is obtained by applying a potential difference between two electrodes. Inside the plasma, the electrons are accelerated and they may bombard at the atoms or ions to yield free electrons and positively charged ions. The positive ions are accelerated towards the cathode and release electrons upon bombardment. The collisions of electrons with atoms or ions may also produce excitation. The excitation collisions, and the subsequent radiative decay to lower levels, resulting in the characteristic light of the "glow" discharge. The ionization collisions create new ions and electrons. While the ion may release electrons from the cathode material by bombardment, the electrons will in turn give rise to new ionization. This multiplication process makes the glow discharge a self-sustained plasma [2]. Due to the various collision processes in the plasma, a large number of different plasma species, such as electrons, ions, atoms, molecules, radicals, etc. can be present. These species may interact with each other, making the glow discharge plasma a complicated gas mixture.

The objective of the present work is to investigate the effects of various parameters on the fundamental properties of low temperature plasma, mainly the glow discharge, and to obtain a better insight of the complex processes in this type of discharge. The investigations were carried out by numerical simulation, and the simulation parameters were set based on the experimental work by Safaai [3] in Plasma Research Laboratory, University of Malaya.

While numerical simulation is normally carried out to complement both theory and experiment, it can also be employed as scientific investigation on its own. In the former case, simulations are widely used by theoreticians in verifying linear and nonlinear theory, and the results are feedback for the improvement of theory. Numerical simulations are also useful to experimentalists in providing explanations to their experimental observations. On the other hand, simulations have been proven very useful as a tool for exploration into new parameters, ahead of doing the comparable theory or experiments. Simulations have also been a tool for discovery, trying out new ideas, or recognizing new and unexpected behavior [4].

The simulations code used in this work is XPDP1 developed by the Plasma Theory and Simulation Group at University of California, Berkeley. The simulation methods of the code are based on the Particle-in-Cell (PIC) and Monte Carlo collision (MCC) models for particle kinetics and collisions respectively. XPDP1 is simulating a one-dimensional bounded electrostatic parallel-plate capacitively coupled plasma system, with a coupled external circuit which includes R, L, and C elements, as well as AC, DC, and ramped current and voltage sources [5].

1.2 Thesis outline

The introduction and the objective of this work are discussed in the **current chapter**. Subsequently, the basic plasma physics of the glow discharge will be reviewed in **Chapter 2** to the extent which is necessary to understand the results of this thesis. **Chapter 3** gives an introduction of the simulation code (XPDP1). In this chapter, the Particle-in-Cell technique, Monte Carlo Collision model, and some other details in this code are presented. Then, towards the end of the chapter, the general structure of the code is shown.

In **Chapter 4**, simulation of a DC glow discharge based on the experimental work by Safaai [3] is described. Comparison with experimental result is presented in the first section, and further investigation on the effects of interelectrode gap length, pressure, voltage and RF discharge are presented in the following sections. The input settings in the simulation are determined based on the experimental work and device. Some of the unknown parameters in the experiment are made by assumption in the simulation. In most cases, the simulation setup is based on the case of 32 mA, 3 Torr and 3 cm interelectrode gap length with reference to the experiment.

Finally, the summary and conclusion of this work are given in **Chapter 5**.