CHAPTER IV

EXPERIMENTAL SET-UP

This chapter describes the experimental set-up for the real time probe measurement. We shall begin with constructions of the typical and compensated electrical probes. The probe-circuit test and the probe-measurement system shall also be explained in this chapter. Finally, measurements in the plasma discharge systems will be exhibited in the last part of this chapter.

4.1 Construction of the Single Electrical Probe

4.1.1 Typical Electrical Probe

For a typical electrical probe [15], there are two important parts in construction, as can be seen in figure 4.1. First, probe tip, which is an imperative part in exploring plasma, is needed to be immerged into the glow region so that charged particles can flow through. In fact, plasma is filled with the energetic charged particles that can bombard the tip; therefore, a material for the construction of the tip needs to be able to resist the heat and corrosion. In this work, Ni-Cr alloy was used as the probe tip, since it has the required properties and is readily-available and inexpensive. The other part is the probe body which is made up with the pyrex tube, as an insulator and yield enough resistance to heat. Inside the tube, a hard coaxial metal line is used as a conductor to connect the probe tip to the voltage source. One end of the metal line is jointed with the metallic junction to support the tip for replacement, and the other end is connected with a female BNC connector. The copper braid shield covers the cable so as to protect signal against noise by connecting the copper to ground. The end of the tube is shield with the araldite glue to prevent gas in the system from leaking through the probe. For the AC discharge measurement, the end of the tube adjacent to the tip is bent to explore the glow region of plasma.

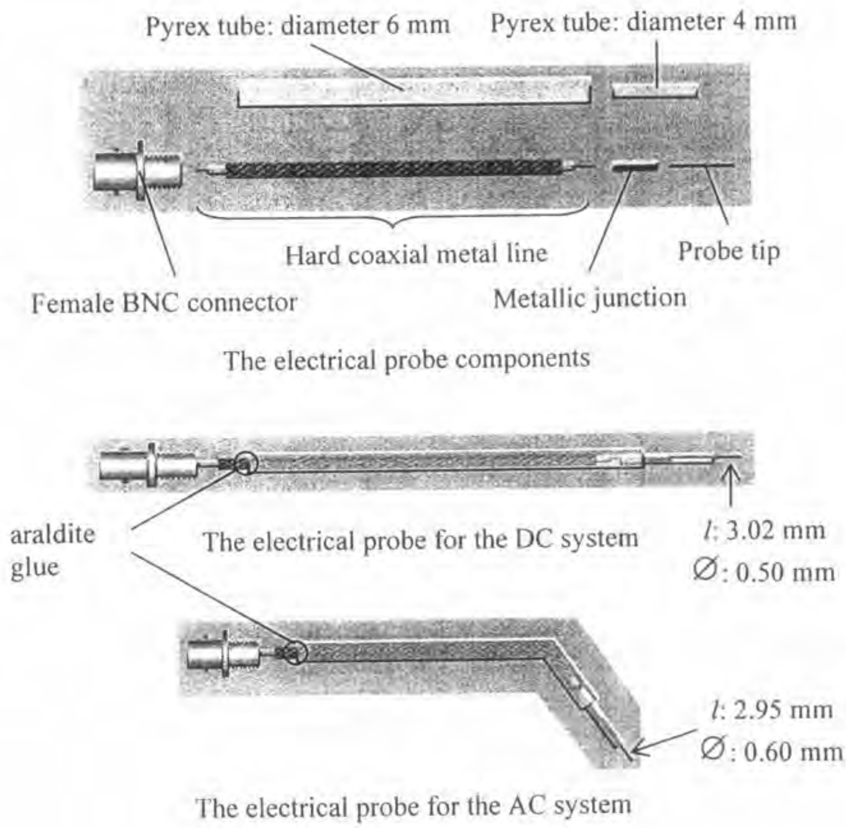

Figure 4.1: The schematic diagram of the typical electrical probe.

4.1.2 Compensated Electrical Probe

In an inductively coupled plasma system, plasma is energized by the radio frequency power source that could interfere with the current signal in the probe measurement. This interference can cause the distortion of I-V characteristics leading to miss-calculation of plasma parameters. To suppress the radio frequency interference, the compensated electrical probe is used to measure the I-V characteristic, instead of the typical one as seen in figure 4.2. The difference of the former probe from the latter is that the latter consists of RF chock. According to researchers [21,24,26], the RF chock can attenuate the RF fluctuation drawn to the probe, and its component is an L-

C circuit which is connected in parallel after the probe tip. The values of the L and C are estimated from

$$f = \frac{1}{2\pi\sqrt{LC}}$$

where f is the radio frequency (13.56 MHz.)

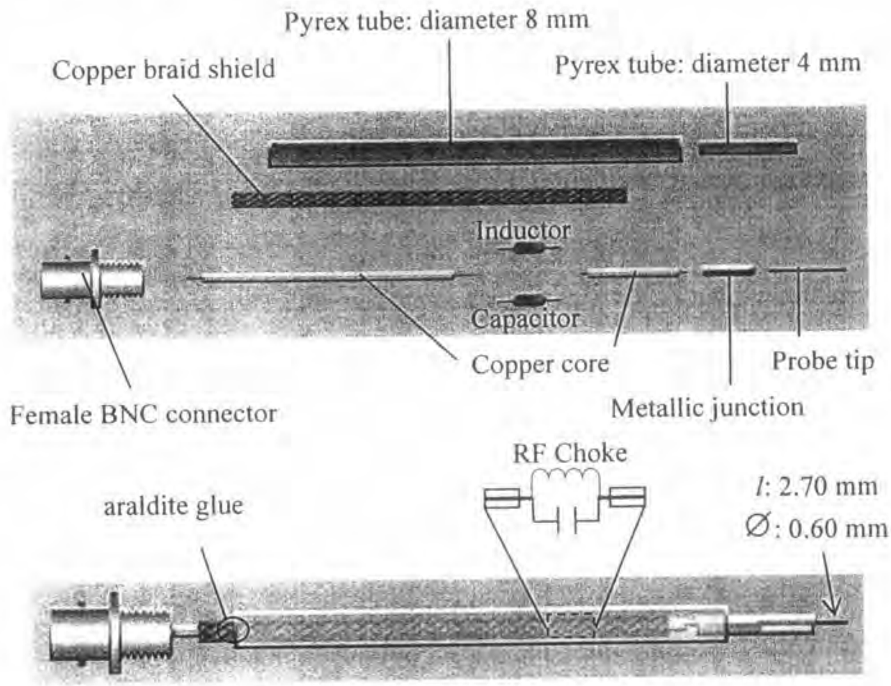

Figure 4.2: The schematic diagram of the compensated electrical probe.

4.2 Circuit Test of the Single Electrical Probe

Before carrying out the probe measurement, the probe circuit was tested. Figure 4.3 illustrates the probe test circuit which consists of a load resistor (10 kΩ 1% error), Hp 4140B pA meter/DC voltage source, and a computer. The equivalent circuit is shown in figure 4.3(b). One end of the probe connected to the pA meter through the resistor, and the other end linked with the voltage source. The computer, which was programmed, controlled the Hp 4140B to sweep voltages from -100 V to +100 V and measure the currents. The current-voltage curve was analyzed by the resistive calculation. The example of the obtained data is illustrated in figure 4.4. From the result, the obtained resistance equaled to 9998.7 Ω.

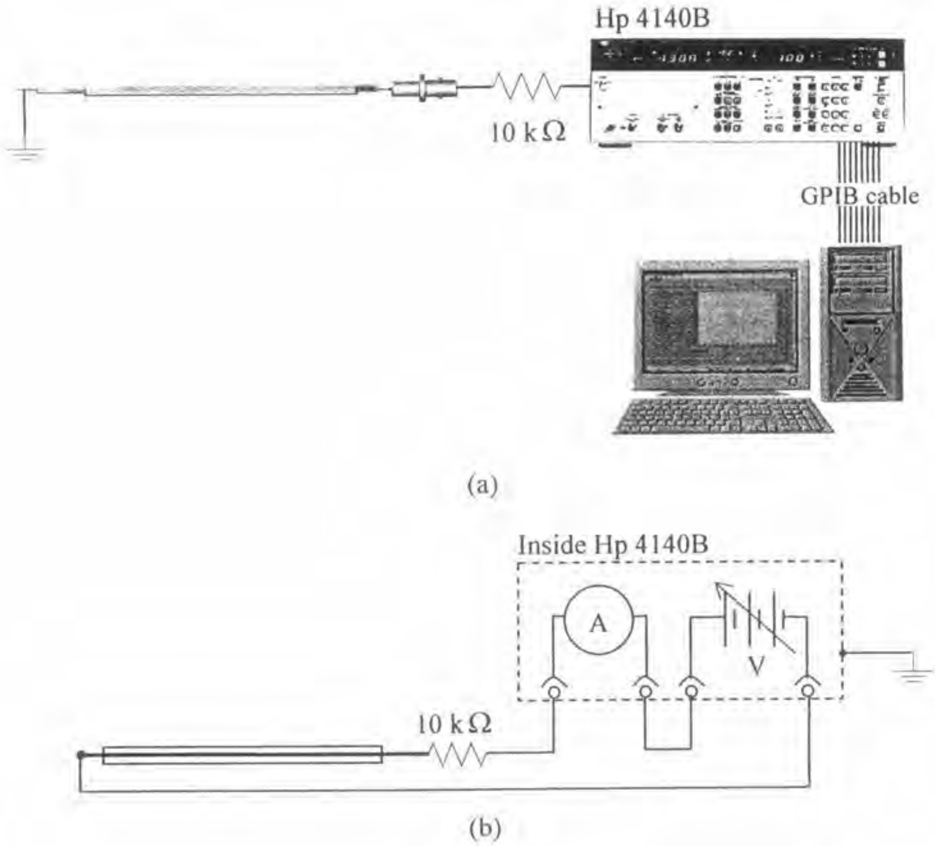

Figure 4.3: The probe-testing circuit, (a) measurement set-up and (b) the equivalent circuit.

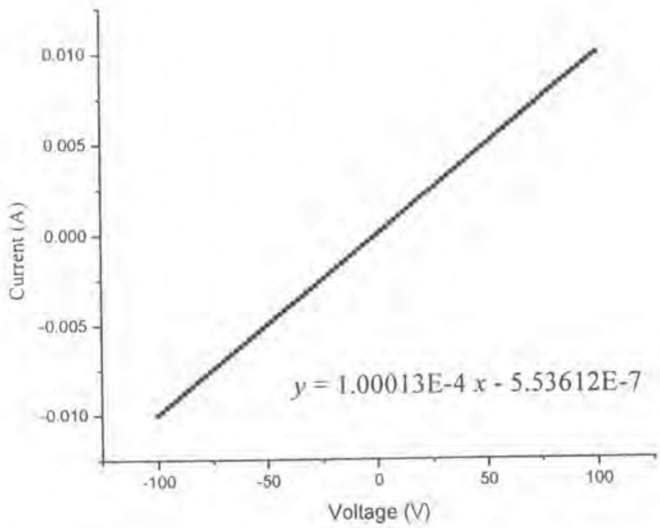

Figure 4.4: The resistance test measurement of the probe-testing circuit.

4.3 Probe Measurement System

From figure 4.5, the typical probe-measured system is shown. The probe connected to the Hp 4140B through a resistor. The resistor 10 kΩ was used in order to limit an excessive current flowing through the device which can tolerate current only up to 10 mA. In the measurement, the device would be controlled by the computer, communicated via the GPIB bus.

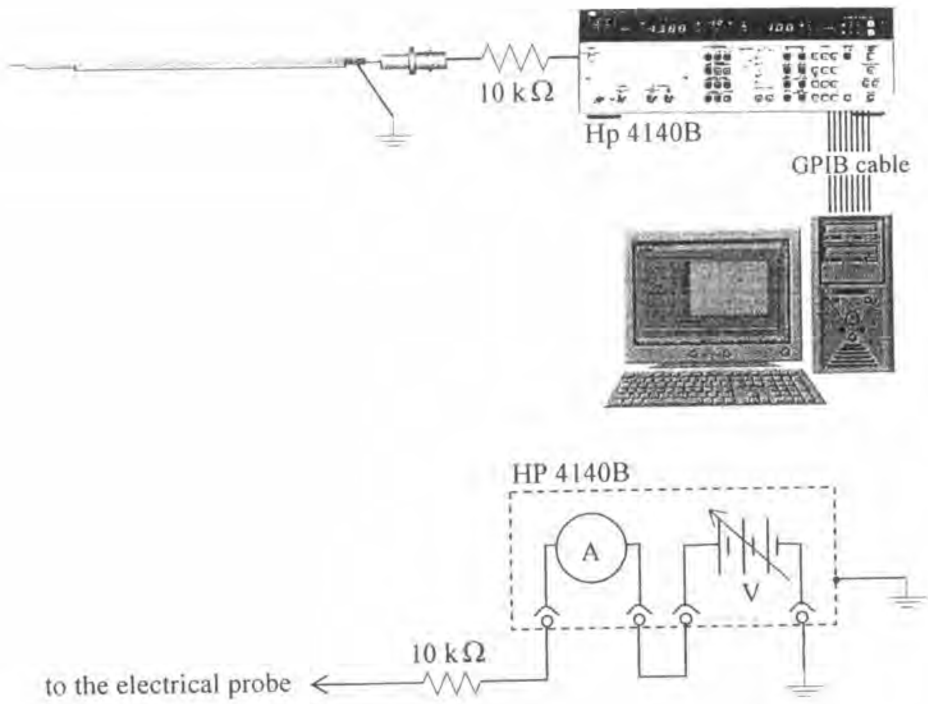

Figure 4.5: The probe-measurement set-up and the equivalent circuit.

4.4 Plasma Analysis

4.4.1 DC Discharge Probing System

The schematic probe measurement diagram for the DC discharge is illustrated in figure 4.6. For a DC discharge [15], the system consists of a vacuum chamber containing gas for plasma generation and the power source that supply to the electrodes. The chamber is evacuated by a rotary pump, and the other entry is used to feed gas. The gauge controller is used to monitor pressure in the chamber. The electrode plate separation is 7 cm in distance. The electrodes are biased by the voltage regulator (variable AC of a variac) through the transformer (220 V: 2.2 kV) in order to step the voltage up ten times. The hollow cathode plate is provided for the entrance of the probe tip to explore the glow region.

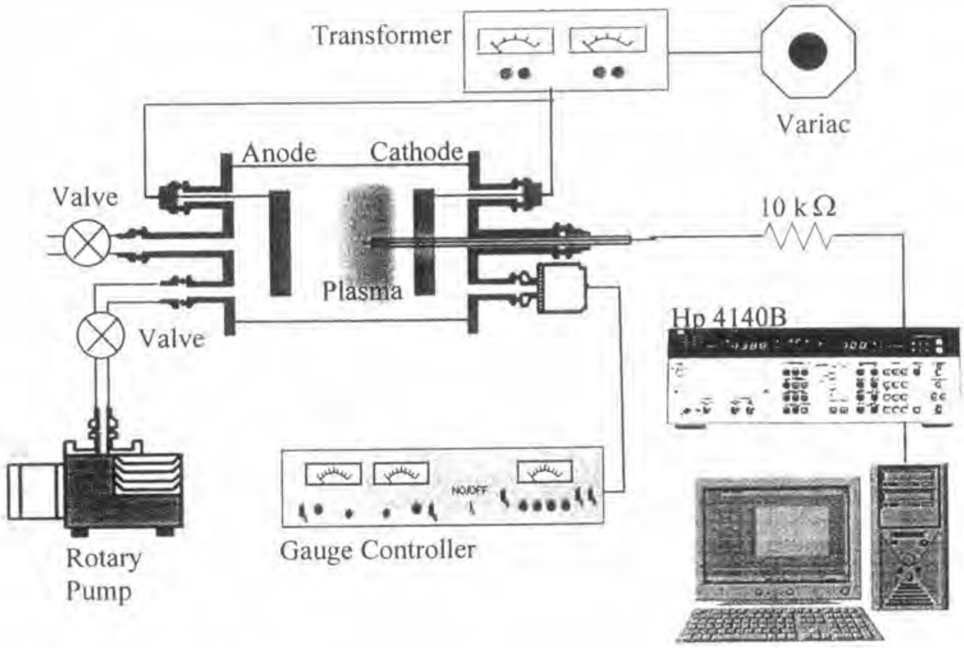

Figure 4.6: The schematic diagram of DC system and probe measurement.

4.4.2 AC Discharge Probing System

Similar to the DC system, the schematic diagram of the AC system is depicted in figure 4.8. The system is supplied by the AC power source with the frequency of 50 Hz, via a step up transformer (x 10 times) before biasing to the electrodes. The electrical plates are located at the middle of the chamber, which separate 5 cm in distance. The chamber is evacuated with the rotary pump, and monitored by a pressure gauge. Argon gas is entered into the chamber through the mass flow controller to generate argon plasma by AC power source.

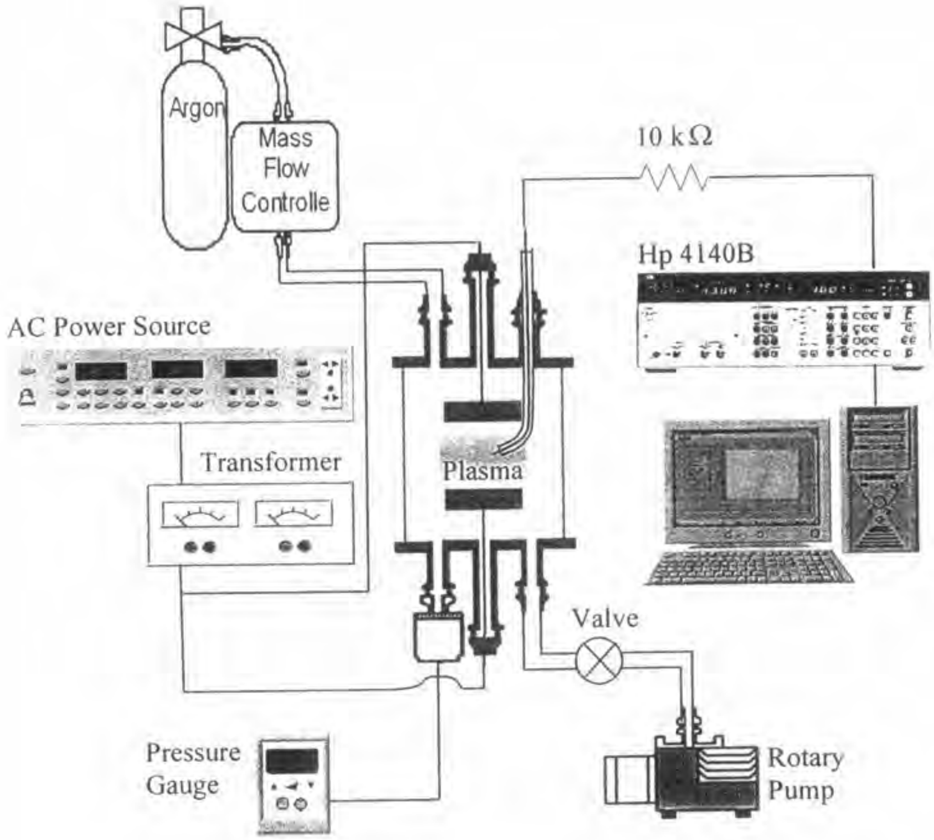

Figure 4.7: The schematic diagram of AC system and probe measurement.

4.4.3 RF Discharge Probing System

Figure 4.7 shows the schematic diagram of the RF discharge system [21]. There are two major components of this system; the reactor chamber and the RF coupling modules. In the figure, the gas evacuation in the reactor is achieved by the turbo-molecular pump backed by the rotary pump; during the process, the pressure is monitored by the pressure gauge. The argon gas is fed into the chamber via the mass flow controller to control the flow rate gas. The RF power coupling modules consist of the RF generator providing power with the frequency of 13.56 MHz, the impedance matching network matching the RF generator impedance of 50 ohm with the plasma impedance (approximate 1 ohm), and the planar coil inducing the secondary current in the chamber to generate the argon plasma.

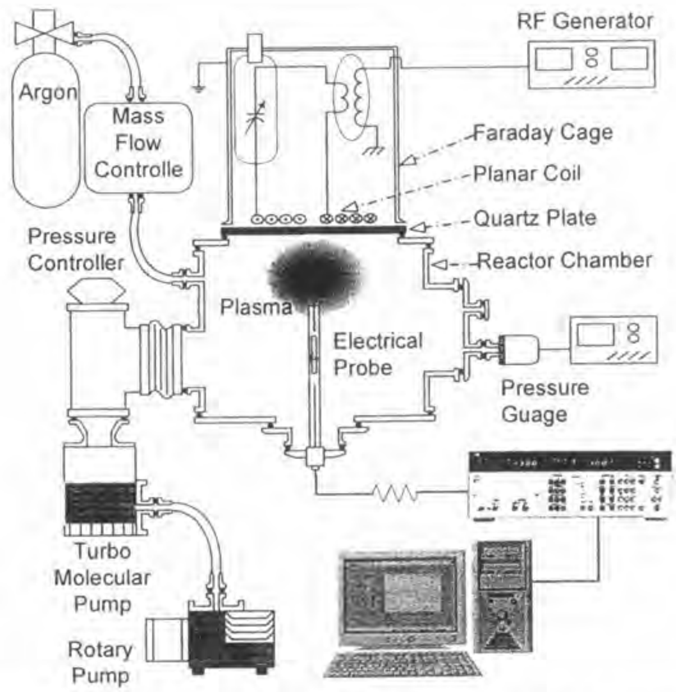

Figure 4.8: The schematic diagram of RF system and probe measure [21].