CHAPTER 2
LITERATURE REVIEW

2.1 The definition of plasma

Plasma is the fourth state of matter. It is unique state and displays a totally different characteristics from the other three states [1]. Plasma consists of positively and negatively charged particles in such proportions that the total charge is equal to zero. The collection of particles is quasi-neutral and display collective behavior. Collective behavior means that the particle motions are controlled by the plasma as a whole rather than by local collisions [6,7]. Since particles in plasma at equilibrium state are always oscillating at a higher frequency than frequency in between two collisions [8]. Most matters in the universe exist as plasma [9].

Plasma can be generated from neutral gas by applying large electric field into the gas, which the energy sent to electrons is sufficient to drive out an electron from an atom on impacting [8,10]. Electron numbers are multiplied rapidly and finally caused the entire gas ionized and becoming plasma.

Studies show that plasma is different from solid, liquid and gas. Some of the conditions that make plasma unique are: [2,9]

1) The Debye Length, λ_D is a measure of the range of the effect of perturbation. λ_D is very small on the scale of the total dimension of the plasma, L; which mean that if the potential in the plasma is perturbed, whether by local concentration of charge arise or external potential are introduced into the system, these are shell out in a distance short compare with L, it can be expressed as

$$\lambda_D \ll \mathrm{L}$$

2) The number of the particle in the Debye sphere, N_D is very large, the Debye sphere has radius λ_D and is centred on the perturbation. This can be expressed as

$$N_D \gg 1$$

3) The mean time between collisions of electrons with neutral atoms, τ is very large on the scale of the frequency of typical plasma oscillation,

$$\tau \gg \frac{2\pi}{\omega_p}$$

where $2\pi / \omega_p$ is the frequency of typical plasma oscillation.

2.2 Radio Frequency Inductively Couple Plasma (RF ICP)

When applying an external electric field into the gas, the ionization process is started. Electrons and ions are produced in the gas phase when electrons with sufficient energy to collide with the atoms and molecules in the feed gas [10]. Radio frequency (RF) plasma can be produced by applying an ac source to a discharge. Many RF glow discharge processes operate at 13.56 MHz. Since 13.56 MHz is a frequency allotted by international communications authorities at which one can radiate a certain amount of energy without interfering with communications [7].

One of most important advantages of RF power is that it can be delivered without the requirement for electrodes in contact with the plasma. The serious disadvantage of electrode in many applications, is impurity of the product introduced by the electrode [7].

RF power can interact with plasma either inductively and capacitively. So there are two types of plasma produced by the RF power. One is the capacitively coupled plasma (CCP) and the second is the inductively coupled plasma (ICP). In the CCP, high frequency voltage is applied to the electrodes. The electrodes may be indirect contact with the discharge plasma. Because the inductively coupled plasma can produced high density and uniformly plasma over a large area, so the ICP system has major advantages over the CCP system in material processing.

RF ICP is excited by an electric field generated from a RF current in a conductor [12]. In this work, a planar coil is used as a conductor. The changing magnetic field of the pianar coil induces an electric field in which the plasma electrons are accelerated. The current-carrying coil either be outside or inside the plasma volume.

ICPs are capable of producing steady-state plasmas having electron densities lying in the range 10^{10} – 10^{13} cm^{-3} [4]. Several applications are reported such as thin-film deposition, plasma etching, and ion sources in mass spectrometric analysis [10].

Many researchers have been studied RF ICP system since this system has many advantages. For examples, Kortshagen, et.al., investigate the E-H mode transition, which results in an increase of the light emission by up to two orders of magnitude and observe a hysteresis of this mode transition [5]. He obtained, the transition from E-H mode is usually accompanied by an abrupt increase in the electron density and the minimum coil current for the E mode may be considerable smaller than the minimum H-mode coil current.

Liew Wai Soon studied the characteristics of RF planar ICP system and investigate the applications of this system in plasma processing of material [6]. Coil current and coil voltage are measured. When he increased the RF Power into the system, coil current and light emission increased. Until, he varied the RF power to one point the coil current decrease suddenly but the light emission to be increase bright. Refleted power of system increased in this point is call "E-H mode transition". And he increased the RF power, the coil current few increased. After that, he decreased power to one point is not same the first point, the coil current increase suddenly. When he studied the result of coil current and RF power almost same Hystersis phenomenon.

Thien Voon Kwan set-up a small planar coil ICP systems, studied its discharge characteristics and application in plasma oxidation [7]. He built and setup the RF-ICP system for study the Argon plasma discharge. He obtained the result in the same Liew.

2.3 Characteristic of plasma in ICP system

Inductively coupled RF discharge typically exhibit two modes of operation, namely, a low-density mode known as the E-mode and a higher density mode known as the H- mode. The transition between these modes exhibits hysteresis [4].

The planar coil can be described using cylindrical coordinates ($\hat{r}$, $\hat{\theta}$, $\hat{z}$) with the origin at the center of the planar coil.

The $\hat{z}$ axis, is perpendicular to the coil and pointing away from the coil into the plasma. The $\hat{r}$ axis is in the radial direction, as shown in Figure 2.1.

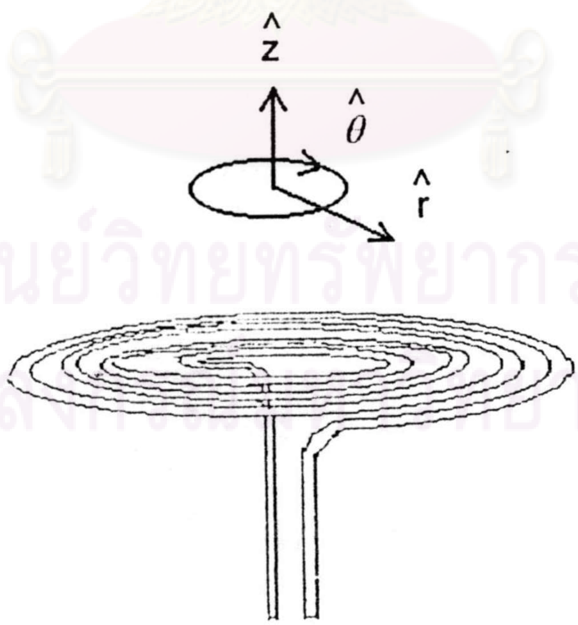

Figure 2.1: The cylindrical coordinates for the planar coil configuration [6]

It is reported by Kortshagen, et.al. [6] that when RF generator forwards RF current passing through the coil produces, by Faraday's law, an oscillating induced electrical field, which is capable of maintaining plasma within the reactor chamber. At low input RF power, the discharge in an ICP characterized by a faint light emission from the plasma and a low electron number density. At this stage, electrostatic field is larger than the induced electric field. This plasma generation mode is called E-mode and plasma is generated by E-mode is usually attributed to the individual loops of the planar induction coil. In the primary, the electrical component, E_r is generated in the $\hat{r}$ direction. And when RF power reaches a certain critical value, there are sudden increases both in the plasma's luminosity and electron number density. This plasma generation mode is called H-mode because it produced by the induced electrical field and the electrostatic field plays only a small role.

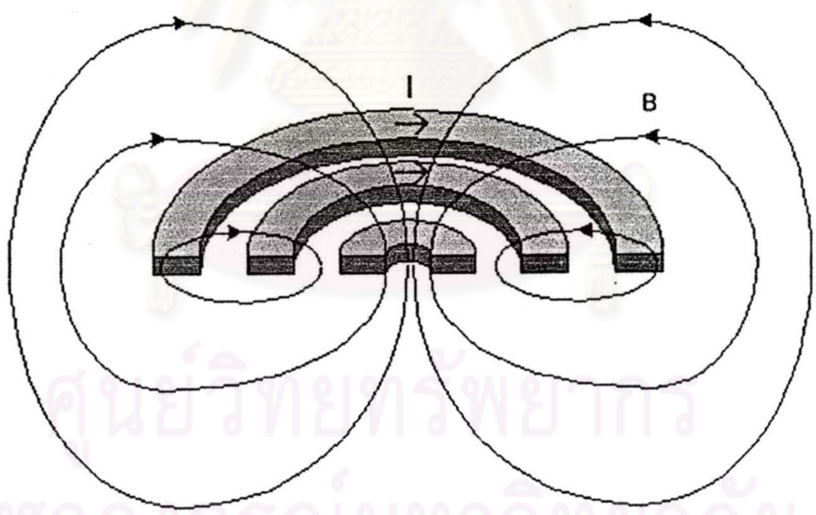

Figure 2.2: Schematic diagram of the RF magnetic field lines near a planar coil [6]

It is reported by Liew Waisoon [6] that, The E-mode to H-mode transition will be accompanied by the succeeding observation:

1) the coil current decrease.

2) the discharge's luminosity increase

3) the plasma current increase

4) the plasma resistance value jump

5) the reactance value, χ, decrease

In this work, polyacetylene thin-film is prepared from monomer vapor of acetylene by using RF-PECVD system. It has many ways in preparation of polyacetylene. Details of polyacetylene are described followed.

2.4 Polyacetylene

The synthesis of a polymer requires the controlled coupling of a large number of monomer molecules to form the polymer chain. A obvious requirement for the monomer is that it shall be functionally capable of coupling to two other units. The most valued properties of synthetic polymers have been their ability to generally act as excellent electrical insulators, both at high voltage and at high frequency [11]. However, it has also been reported that conductivity of some polymer can be varied depending on their growth condition. One of the famous example is polyacetylene which it can become excellent conductor after film doping process [11].

Polyacetylene is normally obtained from acetylene via polymerized process [12]. The delocalized electrons of the alternating single and double bonds between carbon atoms give polyacetylene its conductive properties. Doping of polyacetylene makes this polymer a better conductor. Polyacetylene is used in rechargeable batteries that will probably be used in electric cars and may also replace copper wires in aircraft because of its lightweight.

Acetylene was discovered by E. Davy in 1836 in England and T.L. Wilson made its commercial production in the USA [12]. Pure acetylene is an odorless, colorless gas. It produced by a process that uses two abundant and inexpensive materials: limestone and coal. Limestone (calcium carbonate) is first converted to calcium oxide, and coal is converted to coke. Calcium oxide and coke react producing calcium carbide, which reacts with water forming acetylene gas, $C_2 H_2$. Acetylene's structure is $H - C \equiv C - H$. The triple bond undergoes addition reactions and structure of polyacetylene is $-[HC = CH]_n-$.

It is reported by Billingham, et.al. [11] that, in the early 1970s Shirakawa and Ikeda demonstrated the possibility of preparing strong, self-supporting films of polyacetylene by direct polymerization of acetylene. The polymer thus produced is a poor semiconductor. Until 1977, when MacDiarmid, et.al. [11], rediscovered the fact that treatment of polyacetylene with Lewis acids or bases can increase its conductivity by up to 13 orders of magnitude. This process involves removal or addition of electrons to or from the polymer chain.