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The Effect of RF Power on ion current and sheath current by electrical circuit modeling

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Abstract:-Plasma is very important in the development of technology as it is applied in many electronic devices such as global positioning system (GPS). In addition, fusion and process of plasma requires important elements, namely, the electron energy distribution. However, plasma glow is a relatively new research field in physics. There has not been found any previous study on the electric plasma modeling. Thus, this study was aimed to study plasma modeling especially to find out what was the difference in the number of density and the temperature of the electron in the plasma glow before and after heated and to discover how was the distribution of electron and ion in the plasma. This research was conducted at Brawijaya University, Malang, Indonesia in the Faculty of Science. This exploration began in the middle of June 2013. The data collection and data analysis were done during a year around until August 2014. In this research, characteristics of plasma were studied to build model of plasma. It utilized MATLAB dialect program examination framework which result in the distribution of temperature and current density. The findings show that there has been a large increase in the number of U, U2 with power, while figures of U1 is stable until middle of curve and then decrease as u but u2 after increase at point then stable. The differences appearing are probably due to the simplifying assumptions considered in the present model. There was a curve between current in sheath and plasma. And time and sheath current increased in the beginning then decreased before they experienced another increase.

Keywords:-Plasma glow, RF power, electron density, electron temperature

I. INTRODUCTION

Plasma is usually said to be a gas of charged particles. Taken as it is, this definition isnot especially useful and, in many cases, proves to be wrong. Yet, two basic necessary(but not sufficient) properties of the plasma are: a) presence of freely moving chargedparticles, and b) large number of these particles. Atomic clocks that fly on global-navigation satellites such as global positioning system (GPS) and Galileo employ light from low-temperature, inductively coupled plasmas(ICPs) for atomic signal generation and detection (i.e., alkali/noble-gas RF-discharge lamps). In this application, the performance of the atomic clock and the capabilities of the navigation system depend sensitively on the stability of the ICP's optical emission (CamparoandFathi, 2009). According to Dose & Fischer (1999), fusion and process plasma requires important elements, namely, the electron energy distribution (EEDF).

A study about RF power effect on the temperature and density of plasma has been done by Camparo and Fathi (2009). Camparo and Fathi (2009) studied the optical emission from an Rb/Xe ICP as a function of the RF power driving the plasma. Surprisingly, they found that the electron density in the plasma was essentially independent of increases in RF power above its nominal value (i.e., "RF-power gain") and that the electron temperature was only a slowly varying function of RF-power gain. The primary effect of RF power was to increase the temperature of the neutrals in the plasma, which was manifested by an increase in Rb vapor density. Interestingly, they also found evidence for electron temperature fluctuations (i.e., fluctuations in the plasma's high-energy electron content). The variance of these fluctuations scaled inversely with the plasma's mean electron temperature and was consistent with a simple model that assumed that the total electron density in the discharge was independent of RF power. Yet, researcher has not find yet previous study on the electric plasma modeling. Thus, this study was aimed to study plasma modeling especially to find out what happened with the characteristics of plasma when the voltage was changed, whether it changed the density and the temperature of the electron, and how the distribution of electron and ion in the plasma was.

II. METHODOLOGY

This research was conducted at Brawijaya University, Malang, Indonesia in the Faculty of Science. This exploration began in the middle of June 2013. The data collection and data analysis were done during a year around until August 2014. It will utilize MATLAB dialect program examination framework. The area of this study will happen at the University of Brawijaya.

III. CONCEPT

Electrons have a much higher speed for a given temperature in light of the fact that they have a mass a few thousand times littler than that of the particles. They will rapidly leave the release and desert the slower particles. After a couple of electrons have left, an electric field develops in the sheath area that holds the electrons. In the sheath area there is a draining of electrons and a much bigger electric field which limits the electrons to the release and hauls the more huge particles out. There is a RF current moving through the release. The electron and particle densities in the sheath can change as a capacity of time. The particle thickness are considered to be static, and there are electron thickness depends on a period inside the sheath. The sheath area is partitioned into three separate zones: the unipolar zone, the move zone, and the semi unbiased zone. In the unipolar zone, there are just particles. In this locale, the densities of electrons and particles are about equivalent, and the electric field in this district ought to be figured utilizing the inclination of the charged particles. At the point when the controlled terminal is much bigger, the voltage drop over the ground sheath is small to the point that it can securely be disregarded. Once the capacitance and the safety are ascertained, the impedance might be recalculated utilizing the first impedance recipe. Where C is the capacitance of both sheaths combined. By taking the complex conjugate to get,

$|z| = | R| + |c|$ ………………. (1)

EXPERIMENTAL SET UP

Building the Model of the Electric Plasma Glow

In term of creating the model of electric plasma sparkle, the specialist will utilize the processing physical science utilizing FORTRAN.The dialect was broadly embraced by researchers for composing numerically concentrated projects, which urged compiler authors to prepare compilers that could produce quicker and more proficient code. The consideration of a complex number information sort in the dialect made MATLAB particularly suited to specialized requisitions, for example, electrical designing. MATLAB is recognized to be the first generally utilized programming dialect upheld over a mixture of workstation architectures. MATLAB has developed essentially throughout the years, bringing about another standard.

Methodologies to Plasma Simulation

In the liquid or continuum technique for plasma reproduction the time advancement of the speed dissemination capacity (Birdsall, & Langdon, 1985) is computed by coupling the Boltzmann or Vlasov transport comparison with the Maxwell comparisons. By "inspecting" the plasma at a point in the stage space the project can give the worth of the dissemination capacity by then, utilizing which other physical parameters of investment might be figured. The movement of each of the individual particles is independently figured. The particles are followed in time as they move in their own particular and in addition remotely connected electromagnetic fields, which are dictated by the Maxwell comparisons. Constrains on the particles are computed utilizing the Lorentz comparison. These strengths focus the change in position and speed of the particles inside a little time interim. As they move, their redistribution in space alters the fields, which are recalculated intermittently. Physical parameters like momentums and number densities, different energies and field amounts are measured at distinctive focuses and times as the yield of the reenactment program. Results got utilizing this strategy are specifically similar to exploratory results, and it has been exceptionally fruitful in reenacting a mixture of non-straight plasma conduct. To incorporate these impacts, strategies have been defined by utilizing Monte Carlo methods (Birdsall, 1991).

IV. PLASMA

When applying a sufficiently high potential variation to two electrodes which are placed in a gas, the latter will split into electrons and positive ions increasing a gas discharge (Braginskii. (1965). This mechanism is illustrated as follows: a few electrons are released from the electrodes because of the universal cosmic radiation. On the other hand, the electrons released from the cathode and collide with the gas atoms by not utilizing a potential difference. The inelastic collisions are significant and points to both ionization and excitation. The excitation collisions which are followed by de-excitations along with the radiation emission are resulting the characteristic term for the “glow” discharge. The collisions of ionization result in new electrons and ions. The electric field accelerates the ions toward the cathode where they emit the new electrons by emission of ion-induced secondary electron. New collisions of ionization which is produced by the electrons will generate new ions and electrons. The glow discharge self-sustaining plasma is formulated by the electron emission processes at both the cathode and ionization in the plasma.

Maxwell-Boltzmann Distribution (Velocity of the Electron)

Plasma parameters are not many changing on the mean free path length, because it result from the plasma particles have Maxwellian velocity distribution (Graille et al. 2007). The kinetic energy of a particle is:

$$\frac{1}{2}mv^2K_B\,T \qquad \ldots\ldots\ldots\ldots\ldots (1)$$

The Maxwell-Boltzmann energy distribution f (w) as a function of the probable particle distribution derived from the velocity distribution is:

$$f(w) = \frac{\partial n_w}{\partial w} = \frac{2}{\pi^{\frac{1}{2}}}\frac{w^{\frac{1}{2}}}{(2K_BT)^{\frac{3}{2}}}exp^{\left(-\frac{w}{2K_B}\right)} \qquad \ldots\ldots\ldots\ldots\ldots (2)$$

This is homogeneous and isotropic. This can be written in terms of the density as

$$f_{m(v)} = n(m|2\pi K_BT)^2\left(-m\frac{v^2}{2}\middle|K_BT\right) \qquad \ldots\ldots\ldots\ldots\ldots (3)$$

If we define $V_{th=(2K_BT)\,|\,m)^{\frac{1}{2}}}$ ……………. (4)

Then $v_{th\,=\,f_m(v)} = \frac{n}{\sqrt{\pi v_{th}}}exp^{(-v^2|v^2{}_{th})}$ ……………. (5)

If we follow this analysis through in 3-D we find

$$f_{m(v)} = \frac{n}{(\sqrt{\pi v_{th}})^3}exp^{\frac{-v^2}{v^2{}_{th}}} \qquad \ldots\ldots\ldots\ldots\ldots (6)$$

It can be shown by differentiation that the peak of this distribution occurs at $v = v_{th}$

Several other important characteristics velocities can be related to temperature in the case of Maxwellian distribution. Where there are a very large number of particles in the thermal and charge equilibrium in an isotropic (uniform) medium, the velocity distribution can be determined statistically and is given by the Maxwell equation.

$$f(u) = du_{n=\frac{4n}{\pi^{1/2}}}(m|2k_bT)^{\frac{3}{2}}u^2exp^{(-mu^2|2k_{bT})} \qquad \ldots\ldots\ldots\ldots\ldots (7)$$

Where T is the average temperature and u the velocity over the range du, n is the particle number density, m the particle mass, and K_B Boltzmann's constant K_B = 1.38 x 10-23.

Temperature of the Electron

a. Temperature of the Electron before the Heat

As already stated in the beginning of this chapter, this study is using neutral temperature of the plasma. According to Porteous (1993) the temperature of electron Argon gas is Te= 2-10 eV. This is the temperature of the electron prior to getting the heat. In this condition the temperature of the ion is Ti= 0.1-0.5 eV.

b. Temperature of the Electron after the Heat

The researcher does not know yet, whether the temperature of the electron will change after the heat is given to the sheath. In order to find the answer of this, the researcher will use the following equation, using the thermodynamic theory.

$$\Delta\,U = Q - W \qquad \ldots\ldots\ldots\ldots (8)$$

Density of the Electron

a. Density of the Electron before the Heat

As it is known already from Porteous (1993), the density of the plasma in neutral temperature of argon gas is np = 1010-1012cm-3. This happens prior receiving heat.

b. Density of the Electron after the Heat

The electron density is closely equal to the positive ion density (Wikipedia, 2013). The density of the electron after the heat can be examined using the Maxwell Boltzman distribution theory.

The following is the equation.

$$E_{AV=\frac{3}{2}}K_BT \qquad \ldots\ldots\ldots\ldots\ldots (9)$$

V. RESULTS

Based on circuit as adopted from De Hoog, &Sluitjer (2013), since Ip as new variabel and at different position, so any equations in paper that I change as below:For the current in the boundary sheat 1, the results from Eqs. (2) and (3) are

$$I_{sheat} = I_0\left[exp\left(-\frac{qU\grave{}f}{kT_e}\right) - 1 + \zeta\frac{qU_1}{kT_1}\right] \mathbf{for} U_1 < 0, \qquad \ldots\ldots\ldots\ldots\ldots (10)$$

If the electron current is saturated ,

$$I_{sheat} = I_0\left[exp\left(\frac{q\left(U_1 - \grave{U'}_f\right)}{kT_e}\right) - 1\right] for\ -\frac{kT_e}{2q} < U_1 < o, \qquad \ldots\ldots\ldots\ldots\ldots (11)$$

If the voltage is too small to lead to charge separation and build a capacitive sheath and

$$I_{sheat} = I_0\left[exp\left(\frac{q\left(U_1 - \grave{U'}_f\right)}{kT_e}\right) - 1\right] + \frac{C_{0G_1}}{4}\frac{dU_1}{dt} for U_1 < -\frac{kT_e}{2q}, \qquad \ldots\ldots\ldots\ldots\ldots (12)$$

If the boundary sheath is formed,

For the boundary sheath 2, the results are similar,

$$I_{sheat} = \in I_0\left[1 - exp\left(\frac{q\grave{U'}_f}{kT_e}\right) + \zeta\frac{qU_2}{kT_e}\right] for\ -\ U_2 < o, \qquad \ldots\ldots\ldots\ldots\ldots (13)$$

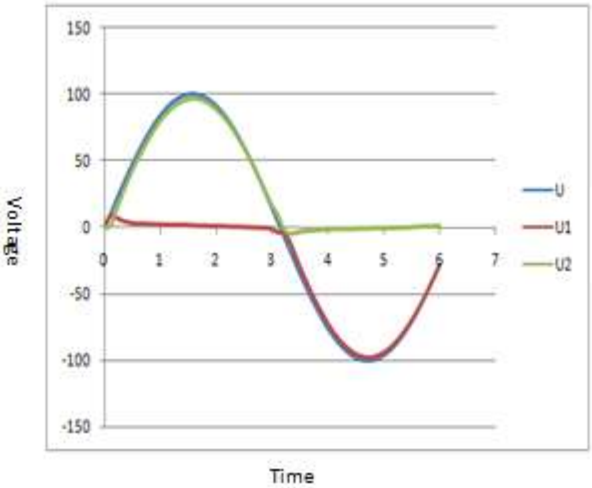
$$I_{sheat} = \in I_0\left[1 - exp\left(\frac{q\left(U_2 + \grave{U'}_f\right)}{kT_e}\right)\right] for\ -\frac{kT_e}{2q} < U_2 < o, \qquad \ldots\ldots\ldots\ldots\ldots (14)$$

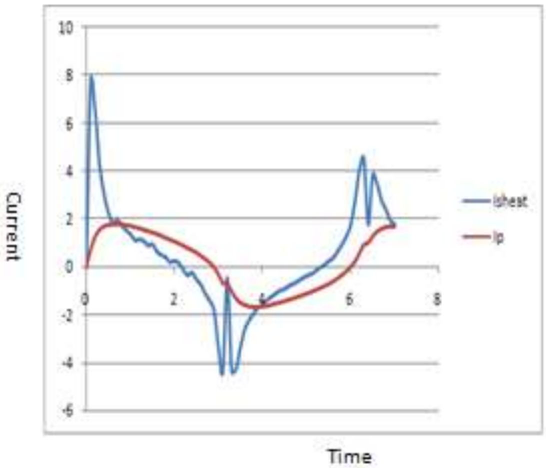
$$I_{sheat} = \in I_0\left[1 - exp\left(\frac{q\left(U_2 + \grave{U'}_f\right)}{kT_e}\right)\right] + \frac{C_{0G_2}}{4}\frac{dU_2}{dt} for U_2 < -\frac{kT_e}{2q}, \qquad \ldots\ldots\ldots\ldots\ldots (15)$$

In numerical calculation, Up can be generated by randomly value with $\frac{dU_p}{dt} = \frac{U_p - Uo_p}{\Delta t}$

So
$$I_{sheat} = C_p\frac{U_p - Uo_p}{\Delta t} + \frac{Up}{R_p} \qquad \ldots\ldots\ldots\ldots\ldots (16)$$

VI. DISCUSSION

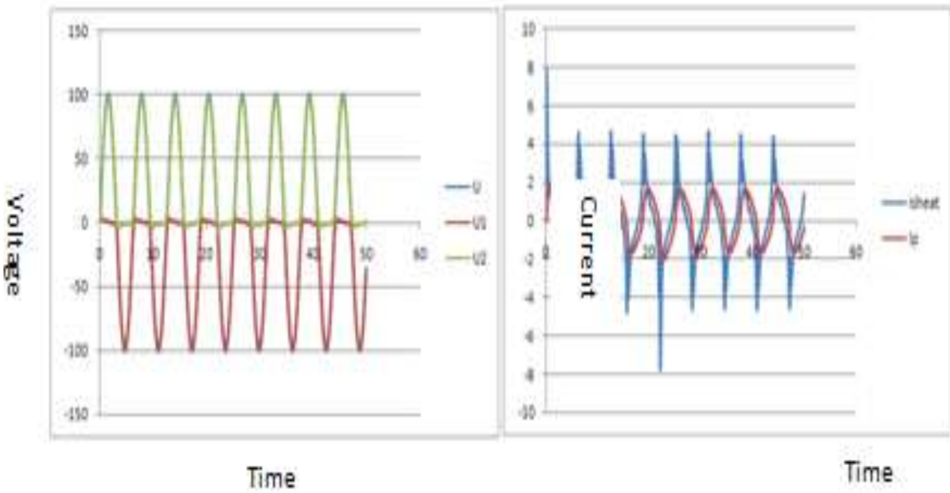




Current Density in the plasma and sheath

Follow chart shows a summary of the procedure used to calculate the sheath current and, current drop in plasma with constant resister. In this chart, the input and output parameters are represented by rounded rectangles, so as to differentiate them from the processing steps. As we can see, in order to obtain the temperature at the system, it is necessary to know the initial current drop and the system. With the obtained temperature, it is possible to calculate the voltage. Distribution of electron and ion current density through the sheath and plasma by different the time, so following the next steps, a new voltage drop can be obtained. The process is repeated until the program output , By the Matlab finite-I it was solved equation 7a,7b,7c,8a,8c and 1pa.moreover that current is obtained by solving 7a,7b,7c,8a,8c and 1pa. The solution was obtained by means of an iterative process that changes current with time until converging with the discharge current density. In other words, the solution of 7a, 7b, 7c, 8a, 8c and 1pa is voltage that produces an electric current density equal. It can be observed that the current density distribution has axial symmetry.

Considering that the simulation layer consumption rate of plasma model is the same in all points, the sheath will work appropriately until the depletion of the simulation layer of system takes place, which result from distribution of temperature and current density. So the differences appearing are probably due to the simplifying assumptions considered in the present model. The graph a: shows curve between power and time the number of voltage various parts. It can clearly be seen that there has been a large increase in the number of u, u2 with power, while figures for visitors u1 is stable until middle of curve and then decrease as u but u2 after increase at point then stable.



Current in sheath and plasma for more circle

The model has explained well the experimental measurements of pulse waveforms and sheath motions for a single or the repetitive pulse operations. This self-consistent circuit model is expected to be used to predict the current and the energy distribution of implanted electron in realistic plasma processes. By using the temperature assumption the electrical power by RF can be established, and consequently, the voltage of sheath and plasma drop or increase can be determined.

The procedure adopted in this paper for assessing the influence of the frequency and waveform of the discharge current supply in the sheath and plasma operation is summarized. We apply a current source I with variable frequency f and waveform /out to the sheath and plasma. V –I characteristics of a discharge using a current at different usi Time ket current at different frequencies. Noti Time he hysteresis or increase of current density phenomenon appears mainly at low frequencies because so more the temperature heat the sheath modulation it can be greater in the plasma which can be more current density of electron and ion and an extra energy is necessary in each cycle to reach work temperature. Growing the sinusoidal current frequency, the increase or lessening at the electric plasma characteristics is reduced in some period. This can be translated into a modulation decrease of the discharge impedance and better electronic control. To validate the model, some typical results obtained. The peak voltage or increase drop for plasma system when the discharge current. The differences appearing are probably due to the simplifying assumptions considered in the present model. The figure b shows curve between current in sheath and plasma and time, sheath current increase in the beginning then decrease then increase.

VII. CONCLUSION

An electrical model for the plasma of a glow discharge envisioned for plasma simulation has been developed in this paper. The model was based on the heat transfer equation for the sheath to the system and implemented in Matlab using the finite current method. Since the model is built on the physical equations that define the plasma behavior over a wide assortment of operation conditions, this system is able to predict the electrical behavior of the plasma for different frequencies and supply current waveforms. The experimental study of the interaction between the discharge of electrons and positive ion is a difficult task to convey out because it necessitates a sophisticated computational Setup to make the measurements; consequently, the plasma model epitomizes an excellent alternative. The capacitor user only needs to Supply the amplitude, heater and current withe reduces the resister of the positive ion and electron current, and for a given model plasma and the sheath geometry, the model predicts the instantaneous increase of voltage with current at the sheath and plasma.

Furthermore, the plasma model enables to know the temperature distribution inside the sheath it lead to know how effect on electron and density of plasma. This is of a great interest provided that the developing of plasma models is strongly related to it. The obtained results using the model have been likened with the current literature, finding a good agreement, even at different work conditions. Thus, we concluded this electric model plasma is a useful tool in sympathetic the interaction between the electron and positive ion that mean behavior of plasma in mandate to advance models of plasma.

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