Ion energy of argon ions incident on the electrodes of an EAE CCRF discharge with energy dependent secondary electron emission model

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The separate control of the ion flux and energy in capacitively coupled radio frequency plasmas (CCPRF) can be contorled by varying the electrical parameters of the circuit. The electrical asymmetry effect (EAE) due to the DC self bias affects the discharge in a manner that the roles of the electrodes can be interchanged by changing the parameters of the voltage source. Here we simulate discharge of this type while using realistic model of the secondary electron emission.

1. Introduction

In applications concerning CCPRF discharges a separate control of the ion flux and energy is needed as a method to control the speed and depth of etched vafers [1,2]. In a symmetrical configuration of electrodes the geometry dictates symmetrical discharge parameters on both electrodes.

A way to change the flux or energy of impinging ions on the etched surface-electrode is to alter the external circuit. In certain conditions, external circuit can significantly affect the plasma parameters in the vicinity of the electrodes [3-6].

By changing the phase angle [theta] of the voltage source function:

$$V(t)=120[\cos(2\pi f t+\theta)+\cos(4\pi f t)], \quad (1)$$

the role of the electrodes interchange. Phase angle variations from $\theta=0$ to $\theta=\pi/2$ change the role of the electrodes as if the electrodes have physically changed places.

By using particle-in-cell simulation we have simulated the development of the discharge by using the secondary electron emission model devised by Phelps and Petrovic [7]:

$$\gamma(\epsilon)=\frac{0.002\epsilon}{1+(\epsilon/30)^{1.5}}+\frac{1.05\cdot 10^{-4}\cdot(\epsilon-80)^{1.2}}{(1+\epsilon/8000)^{1.5}}, \quad (2)$$

for dirty electrodes, where the second therm is zero below ion energy of 80eV. This model describes more realistically the behaviour of the discharge in the manner of two coupled processes: charged species production by electrons in the sheath and production of electrons on the electrode by ion bombardment.

Considering that the production of electrons depends on the energy of the ion hitting the electrodes, two main characteristics affect the discharge: the ion energy distribution on the electrodes and the flux of ions. Also these two parameters of the plasma are important from practical point of view of application in the industry for etching and deposition.

In the following sections we will investigate this two parameters for a discharge in pure Ar at 100Pa, with external circuit of the form described in equation 1, coupled with a 100nF/m^2 capacitor to a standard GEC cell like geometry.

2. The electric asymmetry effect with realistic secondary emission model

In this section we show the electrical asymmetry effect in the simulated discharge as described in the end of the previous section. The main parameters that should be controlled for applicability of EAE are the ion energy and ion flux.

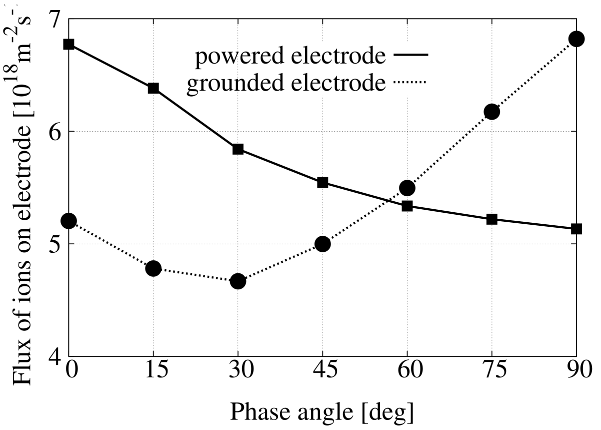

Figure 1. Flux of ions hitting the two electrodes in dependence of the phase angle. The grounded electrode becomes “powered” at $\theta=\pi/2$.

In figure 1 flux of ions on both electrodes is shown, where the powered electrode and grounded electrode are properly denoted. We can see that the parameters for this discharge are well chosen as the electrodes are really interchangeable by varying the θ parameter of the external voltage source. Following the flux also the mean ion energy changes as can be seen on figure 2.

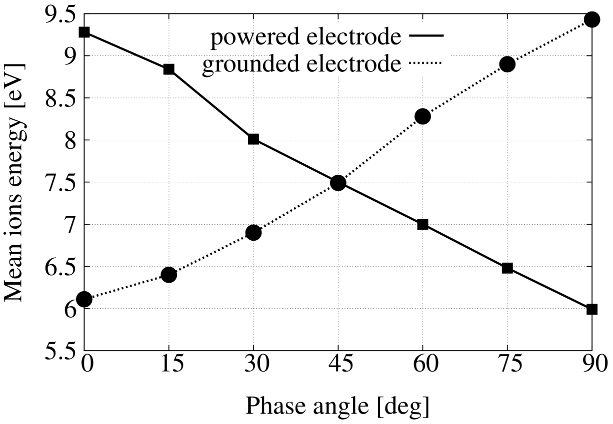

Figure 2. Mean energy of ions hitting the two electrodes in dependence of the phase angle.

In combination with these results one can comment on the effect on the overall discharge parameters because as this processes of changing the flux and energy are useful for practice, this parameters also dictate the production of secondary electrons. The secondary electron production governed by equation 2 depends on the ion energy distribution function (IEDF) on the electrodes. Here we can show this two functions on the powered and grounded electrode for two farthest cases (θ =0 and θ=$\pi/2$).

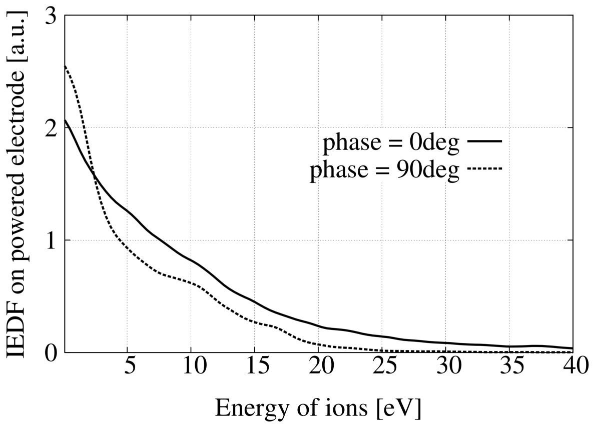

Figure 3. Ion energy distribution function on the powered electrode for two cases where electrodes have interchanged their places.

On figure 3 we see that the IEDF is also changed during the EAE this leads to change in the effective production of secondary electrons. In this case more ions hitting the electrode at lower energies produces less secondary electrons and vice versa.

Secondary electrons are important for ionization of the background gas, as can be seen from figure 4 modifying the overall ionization profile. Conclusion is that if an energy dependent model of secondary electron production is used, the secondary gamma becomes also a part of the EAE. For certain types of discharges (high pressure) the secondary emission on the electrodes is important as a process for sustaining the discharge, thus the model of the secondary electron gamma becomes important parameter for simulation.

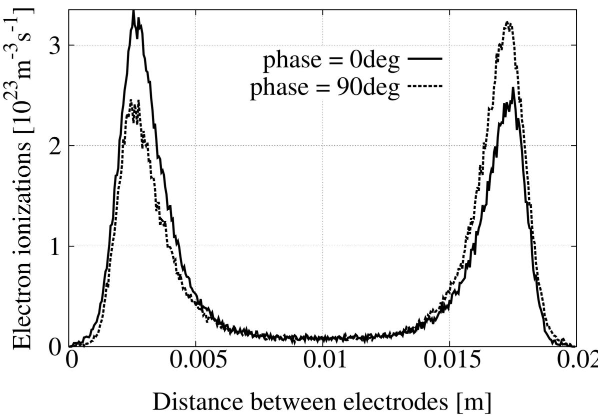

Figure 4. Ionizing collisions of electrons with background argon gas. Two graphs correspond to two different phase angles of the source function.

3. References

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