EFFECT OF ELECTRON EMISSION ON RADIO-FREQUENCY PLASMA SHEATHS

O.Yu. Kravchenko, G.I. Levada, I.S. Marushchak, A.V. Vakulenko

National Taras Shevchenko University of Kyiv, Volodymirs'ka str. 64, 01033 Kyiv, Ukraine

In this article it is studied the influence of electron emission on sheath parameters near electrodes in radio-frequency discharges with the magnetic field. We considered the one-dimensional radio-frequency discharge in argon between plane electrodes separated by a gap d at various neutral gas pressures, electron emission currents and magnetic field values. The computer simulation is carried out using PIC/MCC method.

Results calculations show that the increasing electron emission current causes the decreasing of radio-frequency sheath width and the oscillation amplitude of the electron front. It leads to the increasing of the ion current to the electrode and the ionization rate near the electrode. It is studied conditions, when the radio-frequency sheath instability is appeared and the influence of a gas pressure, a magnetic field value on this phenomenon.
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1. INTRODUCTION

The problem of reduction mass transfer between surface and plasma sheath is of great interest in many plasma applications such as plasma processing [1] and controlled nuclear fusion [2]. The unipolar arc is the crucial phenomena responsible for the mass transfer in plasma devices. This arc is a breakdown caused by the potential drop between the plasma and electrode surface. If the plasma sheath potential is sufficient to ignite and sustain arching, an unipolar arc can occur. The parameters of the sheath and its stability conditions are changing because of electron emission [3]. In fusion devices the magnetic field is also of importance.

The initial phase of the onset of electrical breakdown in discharge is characterized by very rapid ionization of surface material which leads to a kind of explosive formation of cathode spot plasma. Electrons will be emitted from spots on a cold cathode if the applied electric field becomes sufficiently strong. Furthermore, dust particles can appear in plasma in consequence of the wall destruction.

Since unipolar arcs appreciably influence the plasma processes in various applications, there is great interest in the plasma community in developing arcing suppression methods. In some articles was proposed the idea to use a high-frequency electric field in order to affect the unipolar arching [4].

The behavior of rf plasma sheaths has been the subject of much scientific study. In this article it is studied the influence of electron emission and dust particles on sheath parameters near electrodes in radio-frequency discharges with the magnetic field.

2. MODEL

We considered the one-dimensional radio-frequency discharge in argon between plane electrodes separated by a gap d at various neutral gas pressures, electron emission currents and magnetic field values. Immobile dust particles with a radius r_d are distributed uniformly in the interelectrode gap with a density N_d. The dust particles collect and scatter electrons. A harmonic external voltage $V_e(t) = V_0 \sin(\omega t)$ at a frequency f=13,56MHz with an amplitude Vo=150 V sustains the RF discharge. The electrode at x=d is grounded.

The computer simulation is carried out using PIC/MCC method, described in detail in [5] for discharges without dust particles and extended for computer simulations of the RF discharge with dust particles.

The Monte Carlo technique [5] is used to describe electron and ion collisions. The collisions include elastic collisions of electrons and ions with atoms, ionization and excitation of atoms by electrons, charge exchange between ions and atoms, Coulomb collisions of electrons and ions with dust particles, as well as the electron and ion collection by dust particles. The electron-argon collision cross-sections used in the model are the same as those used in [6]. The Coulomb cross-section σ_{coul} for electron and ion scattering by immobile dust particles is taken from [7]. The cross-section for collection of an electron or ion by a dust particle is taken from [8].

3. NUMERICAL RESULTS

Computer simulations were performed for various electron emission currents from electrode, magnetic fields, neutral gas pressure.

In fig.1 it is shown ion density spatial distributions in radio-frequency sheath near powered electrode for cases with different electron emission currents. Neutral gas pressure was $p = 0.1\,Torr$ and magnetic field B was absent. We can see that at the increasing of the electron emission current from electrode the ion density is increased in sheath. It is consequence of the rate ionization increasing near the emitting electrode.

The results show the existence of the central quasi-neutral region and non-neutral RF sheaths close to both electrodes. In the quasi-neutral part of the interelectrode gap electric field E=0 so that the sheath edge is a point between this region and the region with $E \neq 0$. As can be seen in the fig. 2, the sheath edge approaches the grounded electrode and is moving away from the opposite electrode between phases $\pi/2$ and $3/2\pi$ of the sustaining external voltage. The width of radio-frequency sheath is decreased at the increasing of electron emission current from electrode. The results of calculations show also that the width of the sheath is decreased at the increasing of neutral gas pressure. It can be explained by the increasing of ion and electron densities near the electrode and consequently by the decreasing of Debye radius.

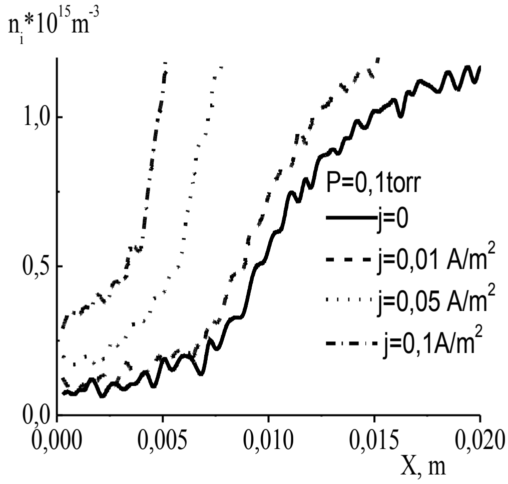


Fig.1. Spatial distributions of ion density in the sheath for different electron emission currents and P=0.1 Torr, B=0

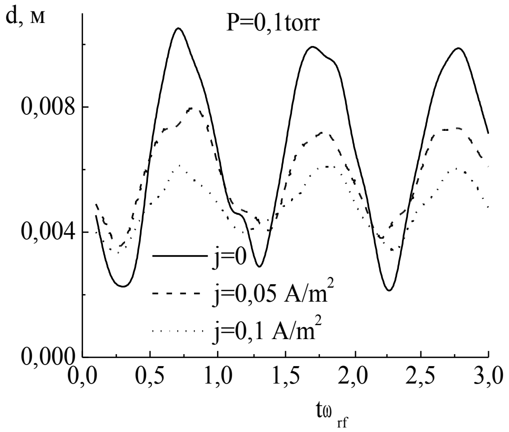
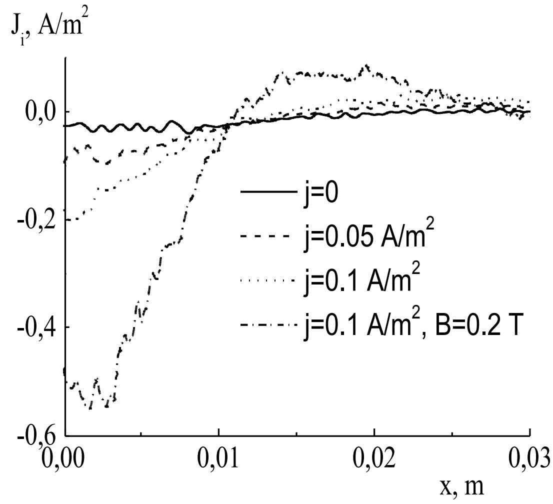


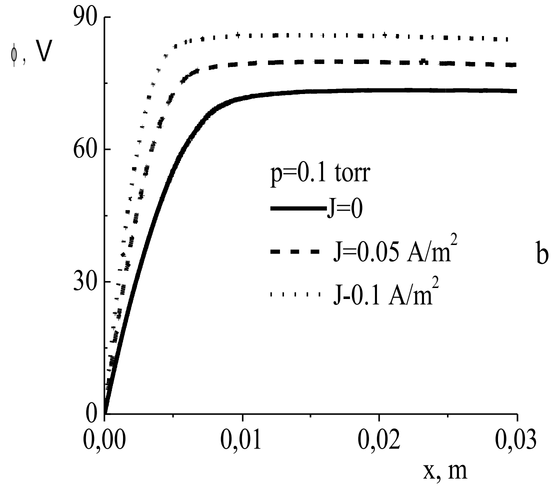
Fig.2. The temporal dependence of sheath width for different electron emission currents, represented on the figure

Fig.3a shows spatial distributions of ion current in radio-frequency sheath for cases represented on Fig.1 and also for case with magnetic field $B = 0.5\,T$, electron emission current density $j_e = 0.1\,A/m^2$. It is seen that the ion current density is increased at the increasing electron emission current density. It is caused by the increasing of the ion density (Fig.1) and the ion energy in radio-frequency sheath. This statement confirms Fig.3b, where spatial distributions of the time-averaged self-consistent electric potential are presented for $p = 0.1\,Torr$, $B = 0$ and different electron emission currents. We can see that the potential drop is increased in sheath at the increasing of the electron emission current. It leads to the increasing of ion energy at the electrode.

Inclined to the wall magnetic field makes difficult an electron movement in the discharge. It leads to the decreasing of the electron recombination on the wall and to the increasing electron and ion densities in the discharge chamber. As a result, the width of radio-frequency sheath is decreased considerably and the potential drop is decreased in the sheath. However, the ion current in the sheath is increased in the presence of magnetic field (Fig.3a) due to the higher ion density.



a



b

Fig.3. Spatial distributions of time-averaged ion current (a) and self-consistent electric potential (b) in rf-sheath

In the presence of inclined magnetic field radio-frequency sheaths doesn't modify due to electron emission current from electrode, since emitting electrons can't move into plasma and don't improve the ionization.

CONCLUSIONS

In this article it is studied the influence of the electron emission from the electrode on the structure of radio-frequency sheaths in low pressure discharges. Results calculations show that the increasing electron emission current causes the decreasing of radio-frequency sheath width and the oscillation amplitude of the electron front. It leads to the increasing of the ion current to the electrode and the ionization rate near the electrode. Inclined to the electrode magnetic field can increases ion current in the sheath and prevents of the sheath modification due to the electron emission from the electrode.

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ВЛИЯНИЕ ЭЛЕКТРОННОЙ ЭМИССИИ НА РАДИОЧАСТОТНЫЕ ПРИЭЛЕКТРОДНЫЕ СЛОИ В ПЛАЗМЕ

А. Ю. Кравченко, Г.И. Левада, И.С. Марущак, А.В. Вакуленко

Исследуется влияние электронной эмиссии на параметры приэлектродного слоя в радиочастотных разрядах с магнитным полем. Рассматривается одномерный радиочастотный разряд в аргоне между плоскими электродами, разделенными промежутком d, при различных давлениях нейтрального газа, токах электронной эмиссии и значениях магнитного поля. Компьютерное моделирование выполняется методом PIC/MCC. Результаты вычислений показывают, что увеличение тока электронной эмиссии вызывает уменьшение ширины радиочастотного приэлектродного слоя и амплитуды осцилляций электронного фронта. Это приводит к увеличению ионного тока на электрод и скорости ионизации газа вблизи электрода. Исследуются условия, когда появляется неустойчивость радиочастотного приэлектродного слоя, и влияние на это явление давления газа и магнитного поля.

ВПЛИВ ЕЛЕКТРОННОЇ ЕМІСІЇ НА РАДІОЧАСТОТНІ ПРИЕЛЕКТРОДНІ ШАРИ В ПЛАЗМІ

О. Ю. Кравченко, Г.І. Левада, І.С. Марущак, А.В. Вакуленко

Досліджується вплив електронної емісії на параметри приелектродного шару в радіочастотних розрядах з магнітним полем. Розглядається одновимірний радіочастотний розряд в аргоні між плоскими електродами, що розділені проміжком d, при різних тисках нейтрального газу, струмах електронної емісії і значеннях магнітного поля. Комп'ютерне моделювання виконується методом PIC/MCC. Результати обчислень показують, що збільшення струму електронної емісії викликає зменшення ширини радіочастотного приелектродного шару і амплітуди осциляцій електронного фронту. Це призводить до збільшення іонного струму на електрод і швидкості іонізації газу поблизу електроду. Досліджуються умови появи нестійкості радіочастотного приелектродного шару і вплив на це явище тиску газу і магнітного поля.