THE INFLUENCE OF HF DISCHARGE ON PLASMA PARAMETERS OF GAS SOURCE WITH INCANDESCENT CATHODE

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An experimental study of the influence of HF power and configuration of the magnetic field on the plasma parameters of the gas source with incandescent cathode was carried out. It is shown that the application HF power into discharge results in reduction of electron temperature. For discharge in decreasing magnetic field the radial distribution of the plasma density in the axial region is more uniform compared with increasing magnetic field.

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1. INTRODUCTION

The experiments about dynamics of radial and longitudinal flows of multicomponent plasma rotating in crossed electric and magnetic fields are presented in works [1, 2]. The received results indicate the possibility of spatial separation of extracted mass flows. However the results must be confirmed by direct mass-spectrometry of outgoing ions flows in axial direction and analysis of ions spectra injected into standard target in lateral direction. Complication for such analysis is comparatively small plasma density $\sim 10^{10}\,cm^{-3}$ and high density of neutral component $(3.5\cdot10^{12}...3.5\cdot10^{13})\,cm^{-3}$, i.e. low ionization degree of neutral gas. Inefficient ionization results in the significant impact of charge exchange processes and so difficulty of received results interpretation. Therefore carrying out of additional work directed to increase of ionization degree and improvement of vacuum conditions during discharge was necessary. These parameters directly depend on work characteristics of the source creating a plasma.

2. DESCRIPTION OF EXPERIMENT AND RECEIVED RESULTS

The requirements early formulated in works [3, 4] to plasma sources for carrying out of experiments on installation DIS-1 are given below:

– gas source must create multicomponent plasma (ionization of gas mixture with greatly different masses);

– vacuum conditions up to $(10^{-4}...10^{-5})\,Torr$ (mean free path of ions before charge exchange onto neutrals must be higher than system size: $\lambda = 1\,m$ at $T = 5\,eV$);

– low plasma temperature (low temperature of electron component reduces the probability of the multiple-charge ions appearance);

– stationary or quasi-stationary work mode (for quasi-stationary mode plasma pulse duration must be 2...5 times higher than transit time of the system by the heaviest plasma ions, i.e. $\tau = L/V_p$, where L – system length, V_p – plasma rate);

– the creation of uniform plasma with density range $(10^{10}...10^{13})\,cm^{-3}$ (higher densities are undesirable as they will bring to collision-dominated regime).

Currently there are many different types of plasma sources [5, 6, 7]. All of them have a number of advantages and disadvantages and partly satisfy requirements mentioned above, but do not satisfy them completely.

The paper deals with an experimental study of the gas source with incandescent cathode. For a stationary source with incandescent cathode time-of-flight factor is not important. However problems of plasma uniformity, ionization degree and created plasma density are still important.

The purpose of the article is to explore the possibility of decreasing of the electron temperature and increasing of the uniformity of the plasma density radial distribution of the stationary gas source with incandescent cathode.

Two variants of magnetic field configuration in plasma source region are realized during the experiments (Fig.1). The switching on the solenoids 2 leads to the creation of the decreasing magnetic field (see Fig.1,a) and solenoids 3 – to the increasing magnetic field (see Fig.1,b) in the plasma source region.

Parameters of arc discharge are similar to those

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described in [1]: $U_{a-c} = 150\,V$, $I_{disch} = (3...5)\,A$. Initially, the cryopump housing – annular cylinder with $L = 35\,cm$, $D = 34\,cm$, located in discharge region, was used as HF antenna. HF field was created by generator with frequency $(3...8)\,MHz$, power $1.5\,kW$. The parameters of created plasma were measured by using a single electric Langmuir probe with $d = 0.5\,mm$, $h = 5\,mm$. The probe construction allowed to carry out the measurements both in radial and longitudinal directions. Magnetic field – $(0...1.5)\,kOe$, discharge voltage – $(0...300)\,V$, vacuum – $(10^{-3}...10^{-4})\,Torr$. The magnitudes of magnetic fields and neutral gas density considerably differ from mentioned in works [8,9].

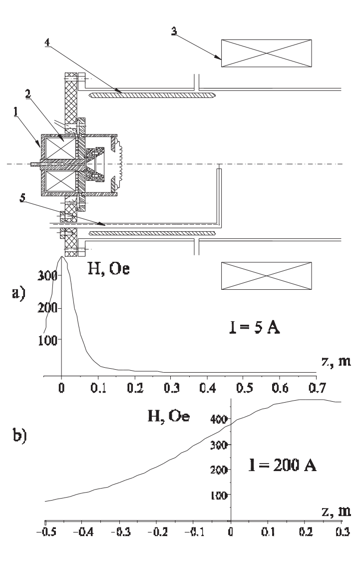

Fig.1 *Schematic view of the experimental installation and two variants of the magnetic field intensity distribution: 1 – plasma source; 2, 3 – magnetic system; 4 – HF antenna; 5 – single Longmuir probe*

The results of probe measurements of plasma parameters radial distribution with a combination of arc and HF discharges are presented on Figs.2 and 3. The probe was located at a distance $27\,cm$ from outlet section of plasma source.

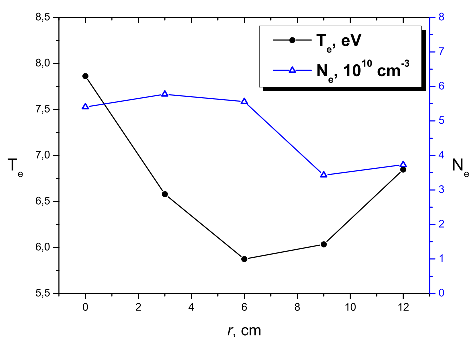

Fig.2 *The radial distribution of density and temperature of plasma created in decreasing magnetic field* $H = 390\,Oe$, $P = 4 \cdot 10^{-3}\,Torr$

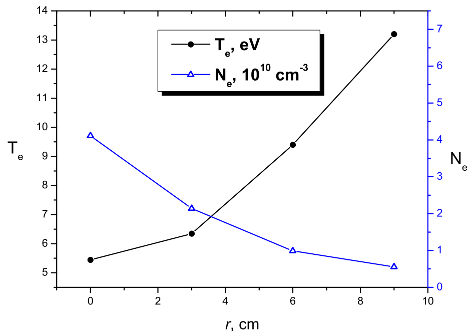

Fig.3 *The radial distribution of density and temperature of plasma created in increasing magnetic field* $H = 390\,Oe$, $P = 4 \cdot 10^{-3}\,Torr$

Comparative analysis of probe measurements showed that in the case of decreasing magnetic field the plasma density distribution in the axial field is more uniform and the average value of plasma density is higher. And, despite the fact that the electron temperature on the axis is higher than in the increasing field, in the rest region temperature is lower. Low electron temperature reduces the probability of the multiple-charge ions appearance.

Tables 1 and 2 show the probe measurement results of the plasma of arc discharge and arc discharge with the introduction of HF power for two configurations of the magnetic field. The measurements of plasma density and temperature were carried out at the axis ($r = 0$) and at $H_{max} = 390\,Oe$ and $P = 2 \cdot 10^{-3}\,Torr$.

Table 1. *The parameters of plasma created in decreasing magnetic field*

	Inc. cathode	Inc. cathode+HF discharge
T_e, eV	12.4	8
N_e, cm^{-3}	$3.8 \cdot 10^{10}$	$3.8 \cdot 10^{10}$

Table 2. *The parameters of plasma created in increasing magnetic field*

	Inc. cathode	Inc. cathode+HF discharge
T_e, eV	4.8	4.4
N_e, cm^{-3}	$5.8 \cdot 10^{10}$	$5.9 \cdot 10^{10}$

As seen the combination of discharges as in the case of decreasing as in the case of increasing the magnetic field reduces the temperature of the electron plasma component. In this case the application of HF power into the arc discharge does not change the plasma density. The difference of the results obtained from those presented in [8, 9] can be explained by the difference in the discharge parameters.

3. SUMMARY

The studies have shown the possibility of increasing the uniformity of the plasma density distribution together with a decreasing of the electron temperature in the axial region. With the introduction of high-frequency power into the plasma created by the gas source with incandescent cathode, the plasma density is not changed, and the temperature of the electron plasma component is decreased. The plasma of discharge in the decreasing magnetic field has more uniform radial distribution of density. The results obtained in the case of decreasing magnetic field better satisfy the requirements to plasma sources.

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ВЛИЯНИЕ ВЧ-РАЗРЯДА НА ПАРАМЕТРЫ ПЛАЗМЫ ГАЗОВОГО ИСТОЧНИКА С НАКАЛИВАЕМЫМ КАТОДОМ

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Проведено экспериментальное исследование влияния ВЧ-мощности и конфигурации магнитного поля на параметры плазмы газового источника с накаливаемым катодом. Показано, что введение в разряд ВЧ-мощности приводит к снижению электронной температуры. Для разряда в убывающем магнитном поле радиальное распределение плотности плазмы в приосевой области более однородное по сравнению с нарастающим магнитным полем.

ВПЛИВ ВЧ-РОЗРЯДУ НА ПАРАМЕТРИ ПЛАЗМИ ГАЗОВОГО ДЖЕРЕЛА З РОЗЖАРЮВАЛЬНИМ КАТОДОМ

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Проведено експериментальне дослідження впливу ВЧ-потужності та конфігурації магнітного поля на параметри плазми газового джерела з розжарюваним катодом. Показано, що введення в розряд ВЧ-потужності призводить до зниження електронної температури. Для розряду в спадаючому магнітному полі радіальне розподілення щільності плазми в привісевій області є більш однорідним в порівнянні із зростаючим магнітним полем.