THE EMISSION SURFACE CALCULATION FOR REACTIVE GAS ION SOURCE WITH DECREASED NEUTRAL GAS INLEAKAGE

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The possibility of calculating the cathode shape of an ion sources for a beam formation system is investigated with the computer code. The acceleration of nitrogen ions with energies from 10 to 50 keV and ion currents of 10…20 mA was investigated [1]. The charged particle beams dynamic in a two-potential electron-optical system is showed. The calculation results are compared with the experimental data. The simulation can be used in the design of injection systems and selection of operating parameters of power sources of technological installations for surface modification.

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INTRODUCTION

In modern industrial technologies ion beams are widely used to clean the surface of processed products [2]. Ion bombardment at energies above 10 keV, i.e. the introduction of ions is used to change the shape, physical, chemical, electrical and magnetic properties of the surface of the processed products. In the world there is an interest in creating equipment for the application of ion beams in the materials irradiation experiment and industrial technologies [3]. The need to create fluxes of charged particles uniformly irradiating the surface at a given energy requires the creation of complex formation and transport systems. The paper [4] considers the use of a process unit with a source of ions of reactive gases and describes the possibilities of using ion beam-assisted technology to study the properties of coatings.

DESCRIPTION

Experiments on the acceleration of nitrogen ions to 50 keV are described in the paper [5]. To obtain a high-current beam of accelerated ions, we used a three-electrode axial-symmetric acceleration-focusing system installed at the output of the gas discharge chamber (GDC) of the ion source (IS). A high voltage was applied between the GDC body (the first plasma electrode – the IS cathode) and the experimental chamber body (the third accelerating electrode), while the working chamber was grounded and the positive potential was applied to the discharge chamber of the IS. A negative potential was applied to the intermediate electrode (the second electrode – focusing), which is 5…10% of the accelerating potential.

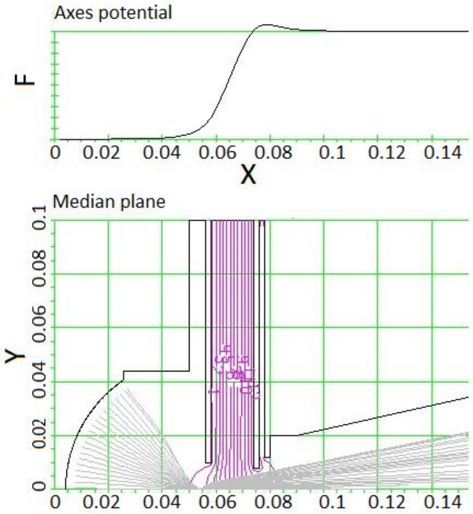
The ion beam leaving the GDC through the cathode grid without feeding a high potential converges and passes through a small-diameter hole electrode. In this case, the ionization of the residual gas ions and the resonant charge exchange of ions on the residual gas in the volume of the accelerating tube occurs, since for ions up to an energy of 4…5 keV their cross section is large. When the focusing power source (PS) is switched on, the ions passing through the diaphragm aperture are accelerated by focusing voltage. At this moment, the current of the order of the total current during acceleration is fixed in the PS circuit of the focusing voltage. This current is due to a large flow of positively charged ions to the second electrode and to the flow of the emission electrons. When the accelerated beam is formed, the pressure in the experimental chamber increases (gas evolution from the walls during bombardment). Therefore, the accelerating voltage is applied smoothly, controlling the leakage current to the electrodes of the system and the pressure in the experimental chamber. When the accelerating PS is switched on, it is necessary to rapidly pass through the voltage rise to 15…20 keV. Since there may be an overload of the accelerating current with the current and the operation of the PS protection system. This current is due to a large flow of charged particles from the volume of the accelerating tube and the working chamber. It causes a parasitic loading of the accelerating PS, heating of the GDC electrodes and the appearance of X-ray radiation. After forming the beam of accelerated ions, the load current of the source of the focusing voltage drops, and the load current of the accelerating voltage source is determined by the beam parameters of the accelerated ions.

CALCULATION RESULTS

The ELION calculation program is designed, which simulates the dynamics of charged particles in the electron-optical system. For the particle current density, the flow continuity equation is satisfied. To calculate the electric potential and the electric field strength, the solution of the Poisson equation is used for given boundary conditions on a uniform rectangular grid. The density of space charge is determined along the trajectories at the grid nodes at a given value of the current of each tube. Trajectories are determined by integrating the equations of motion in given fields for given initial conditions. The emission current is limited by the space charge and is determined for each current tube. The solution is a step-by-step approximation. The distribution of the grid potential is found, the emission current density is determined, the trajectories of the current tubes and the distribution of the charge density at the grid nodes are found. After that, the calculation step is repeated. To suppress the oscillations of the numerical solution, the relaxation of the emission current is used. The relaxation coefficient can be determined.

The program allowed to simulate the system of formation of the ion flow of the process unit. The shape of the electrodes of such systems is carefully modeled, and when assembling a high accuracy of repetition of the calculated geometry is required. The two-potential system ensures the formation of a wide-aperture accelerated ion beam on the target in the experimental chamber (see Figure).

The presence of a focusing potential prevents the flow of electrons along the axis of the accelerating tube from passing to the plasma electrode. The presence of a focusing potential contributes to an increase in the current density of ions, which in the aperture of the diaphragm of the plasma electrode is equal to several tens of milliamps per square centimeter (5…30 mA/cm^2). One method of increasing the current density is to reduce the gap between the diaphragm of the plasma and the focusing electrode. However, there are certain design and electrical limits that prevent a significant reduction in this distance. Due to the finite axial size of the electrodes and the diameter of the holes in them, this distance can not be significantly reduced.



Forming a beam of a two-potential system

CONCLUSIONS

In this work the dynamics of particles in a complex electron-optical system have been calculated. The purpose of the calculations is to check the influence of the emission shape, taking into account the space charge of the beam, taking into account the electric strength, determining the optimal stresses on the cathode of the ion source and the hole electrode, in which the ion beam has the required transverse dimensions, longitudinal and transverse velocities. The performed calculations show the possibility of forming a wide-aperture ion beam with a homogeneous current density distribution on the target. The results of the calculation are consistent with the experimental estimates of the beam current by the probe technique.

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РАСЧЕТ ПОВЕРХНОСТИ ЭМИССИИ ИСТОЧНИКА ИОНОВ РЕАКТИВНЫХ ГАЗОВ С ПОНИЖЕННЫМ НАТЕКАНИЕМ НЕЙТРАЛЬНОГО ГАЗА

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Данная работа посвящена исследованию возможности расчета формы поверхности эмиссии системы ускорения ионов реактивных газов. Решается самосогласованная задача динамики заряженных частиц в двух-потенциальной электронно-оптической системе. Исследуется система ускорения ионов азота с энергией от 10 до 50 кэВ с током 10…20 мА. Проведено сравнение результатов расчета с экспериментальными данными. Расчеты могут использоваться при конструировании систем инжекции ионов и выборе рабочих параметров источников питания технологических установок для модификации поверхности.

ОБЧИСЛЕННЯ ПОВЕРХНІ ЕМІСІЇ ДЖЕРЕЛА ІОНІВ РЕАКТИВНИХ ГАЗІВ ІЗ ЗНИЖЕНИМ НАТІКАННЯМ НЕЙТРАЛЬНОГО ГАЗУ

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Ця робота присвячена дослідженню можливості розрахунку форми емісійної поверхні для системи прискорення іонів реактивних газів. Наведено чисельний розрахунок самоузгодженої динаміки заряджених частинок у двопотенційній електронно-оптичній системі. Досліджуються властивості системи прискорення іонів до енергії 50 кеВ зі струмом 10…20 мА. Проведено порівняння результатів розрахунку з експериментальними даними. Розрахунки можуть використовуватися при конструюванні систем прискорення іонів та вибору робочих параметрів джерел живлення технологічних установок для модифікації поверхні.