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Original research article

Effective parameter in extraction of ion-beam from a diode system

Khalid A. Yahya, Oday A. Hussein*

Department of Physics, College of Science, Al-Nahrain University, Baghdad, Iraq

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ABSTRACT

The effects of the gap distance between the electrodes and the extraction voltage on the spot, shape and the kinetic energy distribution of the argon ions were studied theoretically for a diode extraction system. The results showed that under specific conditions, a good focusing to ion-beam was found, where the dimensions of the ion spot were reduced by about 28.6% at gap distance 8 mm and extraction voltage -35 kV with best controlled for hitting ion to the extraction electrode. Also, a homogenous kinetic energy distribution of the beam can be found at distance between 10 mm and 25 mm.

1. Introduction

The extraction of the ion beam at a specific focusing from plasma ion sources is important in different applications such as, in electromagnetic separators, ion implantation and other practical system [1–7]. Diode, triode, multigap, multiaperture, mesh and postacceleration are different extraction schemes using for extracting beams from ion source [3,8–10]. The ion-beam extracted from the plasma ion source is influenced by several parameters, including: geometrical shape of the electrode, dimensional of the electrode, extraction voltage and its kind, space charge, and plasma boundary [11–13].

In this work, the affecting extraction parameters of a diode system, such as, including the extraction voltage, drain ion current in extraction electrode and the distance from plasma boundary and extraction electrode and the distributions of kinetic energy for argon ion beam are tested with the aid of simulation software SIMION 8.1.

2. Extraction of ion-beam

It is important to study the physics of an ion source extraction system to obtain the ion-beam with high quality and intensity. In a discharge chamber of plasma source, the ions are generated and can be accelerated outside the plasma electrode by applying a potential (extraction voltage) on the extracted electrode.

The extracted ion current density is limited by space charge of ions and plasma density. The current density J can be determined using Child-langmuir law [14–16]:

$$J = \frac{4}{9} \varepsilon_O \sqrt{2\,e\,Z/m_i}\, \frac{V_{ext}^{3/2}}{d^2}, \tag{1}$$

where Z is the ionization state, e electron charge, m_i ion mass, d extraction gap distance, ε_o vacuum permittivity and V_{ext} extraction voltage.

* Corresponding author.
E-mail addresses: drkayahya2005@yahoo.com (K.A. Yahya), oah@sc.nahrainuniv.edu.iq (O.A. Hussein).

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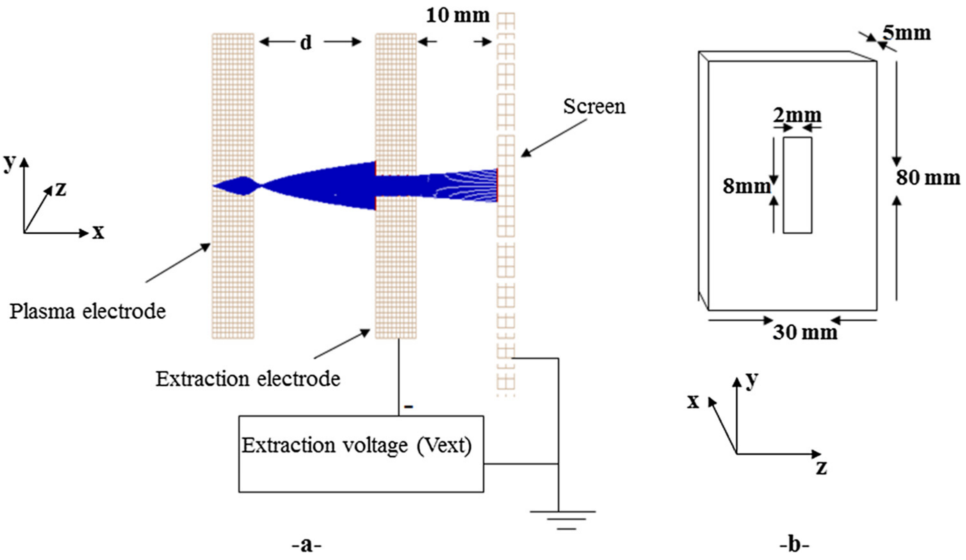

Fig. 1. Schematic of: a- a diode extraction ion-beam system. b- an extraction electrode dimension.

The total ion-beam current Ib from the slit aperture is given by [17]:

$$I_b = J A, \tag{2}$$

The energy of ion-beam, E_i, is given by:

$$E_i = e Z V_{Plasma}, \tag{3}$$

where

$$V_{Plasma} = V_{ext} + V_P, \tag{4}$$

where V_P is plasma potential of order 10 V and can be neglected $V_P \langle\langle V_{ext}$

The perveance P of geometric quantity for extraction system is given by [18]:

$$P = \frac{I_b}{V_{ext}^{3/2}}, \tag{5}$$

3. Proposal extraction system

Fig. 1 illustrates main parts of the proposal diode extraction system and shows their dimensions. The argon ions with a gaussian distribution and an initial energy 150 eV were extracted throughout a rectangular slit (2 × 8 mm2) at the middle of plasma and extraction electrode.

The effective parameters on extracted argon ion beam are investigated at d = 10 mm from the extraction electrode with the aid of the computer simulation package SIMION 8.1.

4. Results and discussions

4.1. Total ion current

The total extracted ion current beam Ib was calculated using Child-langmuir law (Eq. (1)) for different values of extraction voltage Vext and extraction gap distance d. The calculations were carried out for different values of extraction gaps d = 8,10,15,20 and 25 mm at different values of extraction voltages Vext = −15, −20, −25, −30 and −35 kV and the results are shown in Fig. 2.

The ion current decreases as the extraction gap d is increasing, while the opposite behavior was found in the relation between the ion current and the extraction voltage Vext as shown in Fig. 2.

4.2. Perveance parameter

The influence of extracted voltage and gap distance on perveance P is clearly demonstrated in Fig. 3 using Eq. (5). The results show that the decreases perveance with increasing the values of gap distance d, while the opposite behavior appears for extraction voltages V_{ext}.