H^- SOURCE WITH VOLUMETRIC-PLASMA FORMATION OF IONS

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In the presented work results of experimental researches of two versions of H^- ions source with axial-symmetric and slot-hole geometry of ions extraction are submitted. Formation of ions occurs in them in a volume of hydrogen plasma (without additives of cesium) due to two-step dissociative attachment of thermal electrons by vibration-excited molecules H_2 [1]. The cross-section of this process quickly grows up to a significant size (>10^{-17} cm^2) with growth of oscillatory quantum number at electron energy of several eV.

In the considered sources optimization of conditions for oscillatory excitation of molecules and for the subsequent formation of negative ions is realized due to creation of discharge system generating in the emission chamber two areas of plasma - peripheral, with rather big fraction of fast electrons and paraxial with cold electrons.

On figure 1 the design of a source with axial-symmetric geometry of formation of ion beam is schematically submitted [2].

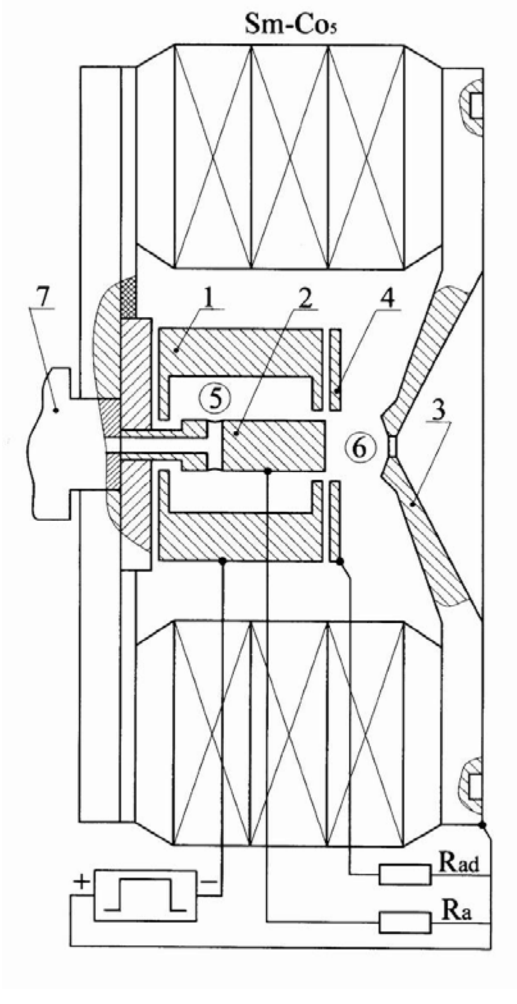

Figure 1. Source with axial-symmetric geometry.

Its magnetic system is executed on the basis of permanent $Sm\text{-}Co_5$ of magnets which create in an interpolar gap induction of magnetic field B_z = 0,09 - 0,12 T. The discharge chamber 5 consisting of the cathode 1 and anode 2 represents inverse gas magnetron which works on the basis of glow discharge in crossed ExH fields. The electromagnetic valve 7 supplies gas magnetron with working gas. Under submission of a pulse of a voltage onto electrodes of the discharge chamber, plasma of a tubular configuration is generated in it. Under the execution of certain conditions [3] plasma penetrates through an annular slot into the emission chamber 6 and reaches the emission electrode 3. For stable current transmission, the additional electrode 4 is placed near a face part of magnetron, on which voltage higher than potential of anode is applied.

Due to formation of double layer before a narrow annular slot on an output from magnetron delivering fast electrons to the area of its volume, in peripheral plasma favorable conditions for oscillatory excitation of molecules are created.

Internal paraxial plasma, formed for the account of diffuse expansion across a magnetic field of peripheral tubular plasma, will contain alongside with the vibration-excited molecules also the enriched fraction of slow electrons as the fraction of fast electrons does not penetrate here because of the action of magnetic filter. Thus, in the internal plasma there are necessary conditions for effective fulfillment of a finishing phase of two-level process of formation of negative ions.

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Extraction of ions from a source is made from paraxial zone of the emission chamber. Suppression of accompanying electrons occurs due to their moving along a magnetic field onto the emission electrode being the anode of a source. Negative ions practically are not subjected to the influence of a magnetic field and at observance of a condition $\lambda_i > d$, they participate in emission of ion beam. Here λ_i - length of free path of a negative ion, d - distance from a place of its formation up to the emission aperture.

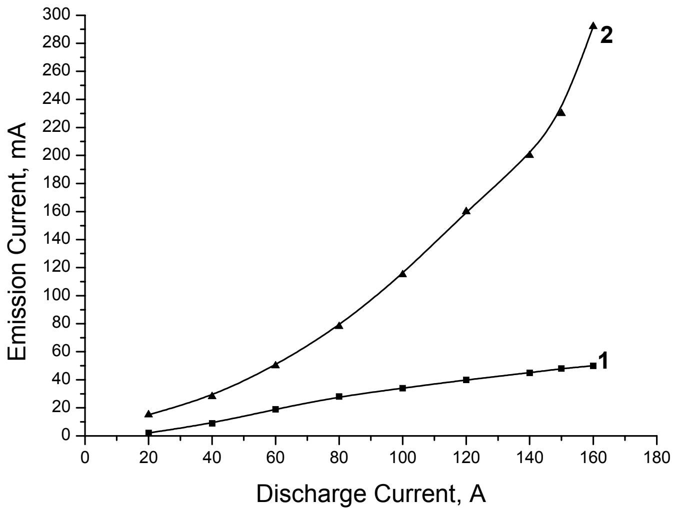

Figure 2. Dependence of negative ions current (curve 1) and accompanying electrons current (curve 2) on discharge current.

On figure 2 dependences of an emission current of ions H^- (curve 1) and a current of accompanying electrons (curve 2) from a discharge current are given. Each point on this curve is received at the optimized value of pressure in the source. At increase of a discharge current, extractive voltage was regulated so that the coordination on perveance was kept. At discharge current I_{dc} = 160A and U = 98 kV ion current I_i = 50 mA is received with emission density of ion current $J \approx 0{,}22$ A/cm^2 and a current of accompanying electrons I_e = 292 mA. From the dependences it is visible, that at the discharge current > 140 A the curve of ion current is bent, and the curve of electron current grows more abruptly. It is possible to explain such behavior of curves by development of fluctuations in plasma with increase of a discharge current and violation of stability of its tubular structure, and also by decrease of magnetization of $Sm\text{-}Co_5$ magnets as a result of thermal influence from hot emission electrode with which they are in good thermal contact.

The basic parameters received on this source, are given below:

Ion beam current I_i	– 50 mA
Ratio I_e/I_i	– 3 - 6
Ion beam energy	–10 - 100 keV
Emission density of a current	~ 0,22 A/cm^2
Impurity ions	~ 3 %
Pulse duration	– (10^{-4} - 10^{-3}) s
Repetition rate of pulses	– (1 - 10) s^{-1}
Life time of source	– (1-2) 10^6 pulses

The lifetime of the ion source was determined by a resource of the electromagnetic gas valve.

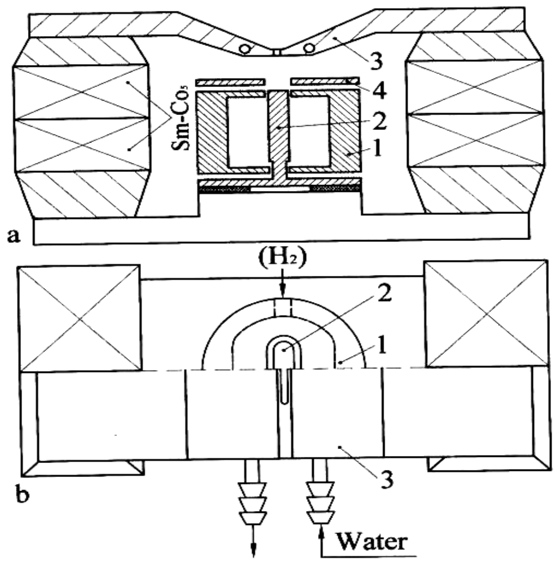

Figure 3. Ion source with slot-hole geometry.

The increase of a current from ion source (without introduction of additional processes responsible for their kinetics in plasma) is possible to obtain due to expansion of volume in which generation of negative ions occurs and the appropriate increase of the area of emission aperture. Increase of the area of emission aperture will be limited by allowable values of phase characteristics of ion beam and by aberrations of ion-optical system. In the version of the source (shown on figure 3) expansion of area of generation of H^- ions is carried out due to formation of internal paraxial plasma as the cylinder in height d with oval section extended along the emission slot.

The area of the emission slot is $2x15mm^2$ [4]. As in the emission area of the source concentration of negative ions is maximal in the paraxial zone, and concentration of electrons is maximal on periphery, then the output of negative ions and accompanying electrons will depend on value Δr, which is equal to distance from perimeter of an emission slot up to a projection of an end of the anode of magnetron onto emission electrode. For reception of acceptable ratio I_e/I_i it is necessary to optimize this value Δr.

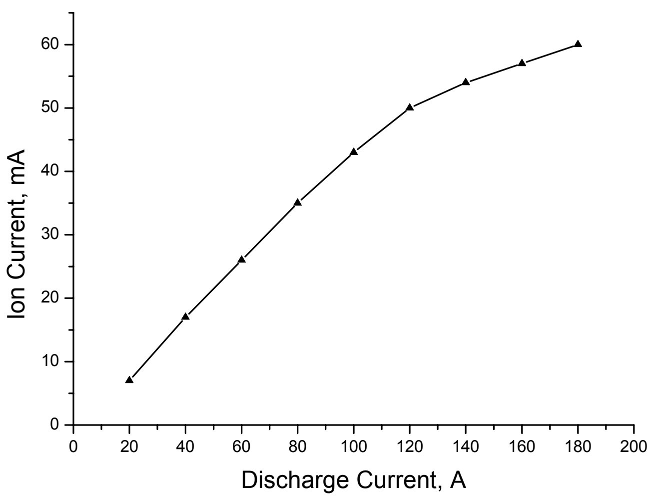

Figure 4. Dependence of H^- ion current on the discharge current.

Carried out experiments showed that in a view of real-life instability of peripheral plasma and no ideal coaxiality of the discharge chamber, value Δ r in this source should be ~ (2 - 3) mm.

On figure 4 dependence of a current of negative ions beam as a function of discharge current is represented. From figure it is visible, that for this modification of the source, current of H^- ions obtains ~ 60 mA. At the further increase of discharge current, instability of the oval form of peripheral plasma begins to appear.

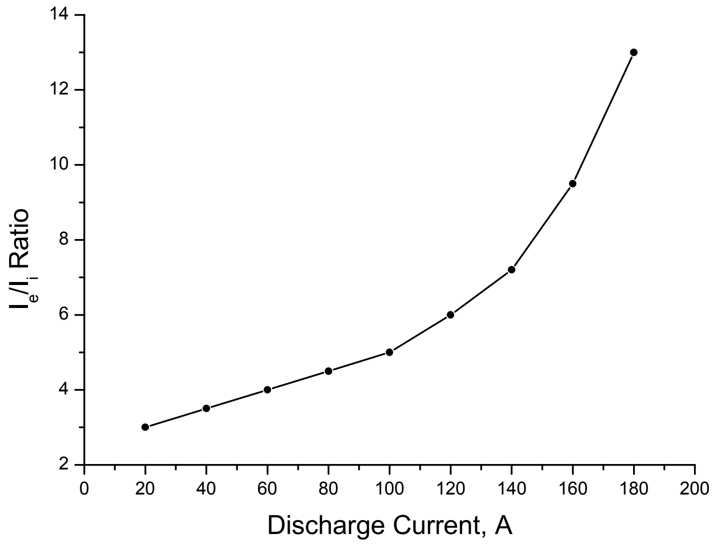

Figure 5. Dependence of I_e/I_i ratio as a function of discharge current.

On figure 5 dependence of I_e/I_i ratio as a function of discharge current at optimum values of pressure in the source is represented. The dependence has a nonlinear character. In this version of ion source the current of accompanying electrons is higher than in a source with axial-symmetric geometry. It can be explain by the fact, that because of the oval form of tubular plasma the appearance of plasma inhomogeneity along the azimuthal direction becomes more probable. Rotation of these inhomogeneities in crossed ExH fields results in rotary oscillations and, accordingly, to emission of fast electrons to the area of emission slot.

In the produced report the ion sources work during long time in the structure of RFQ accelerator of the Sukhumi Institute of Physics & Technology.

The further increase of negative ions current in the source we suppose to obtain due to introduction of additional active mechanisms, which will allow increasing the concentration of slow electrons and vibrationally exited molecules. The concentration of slow electrons can be increased by slowing down fast electrons of peripheral plasma in the emission chamber using reflective electrode. The concentration of vibration-exited molecules can be increased, by placing in the end face of electrode 2 (fig.1) a metal-hydride, capable desorbing vibration-exited molecules of hydrogen under certain conditions [5].

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