

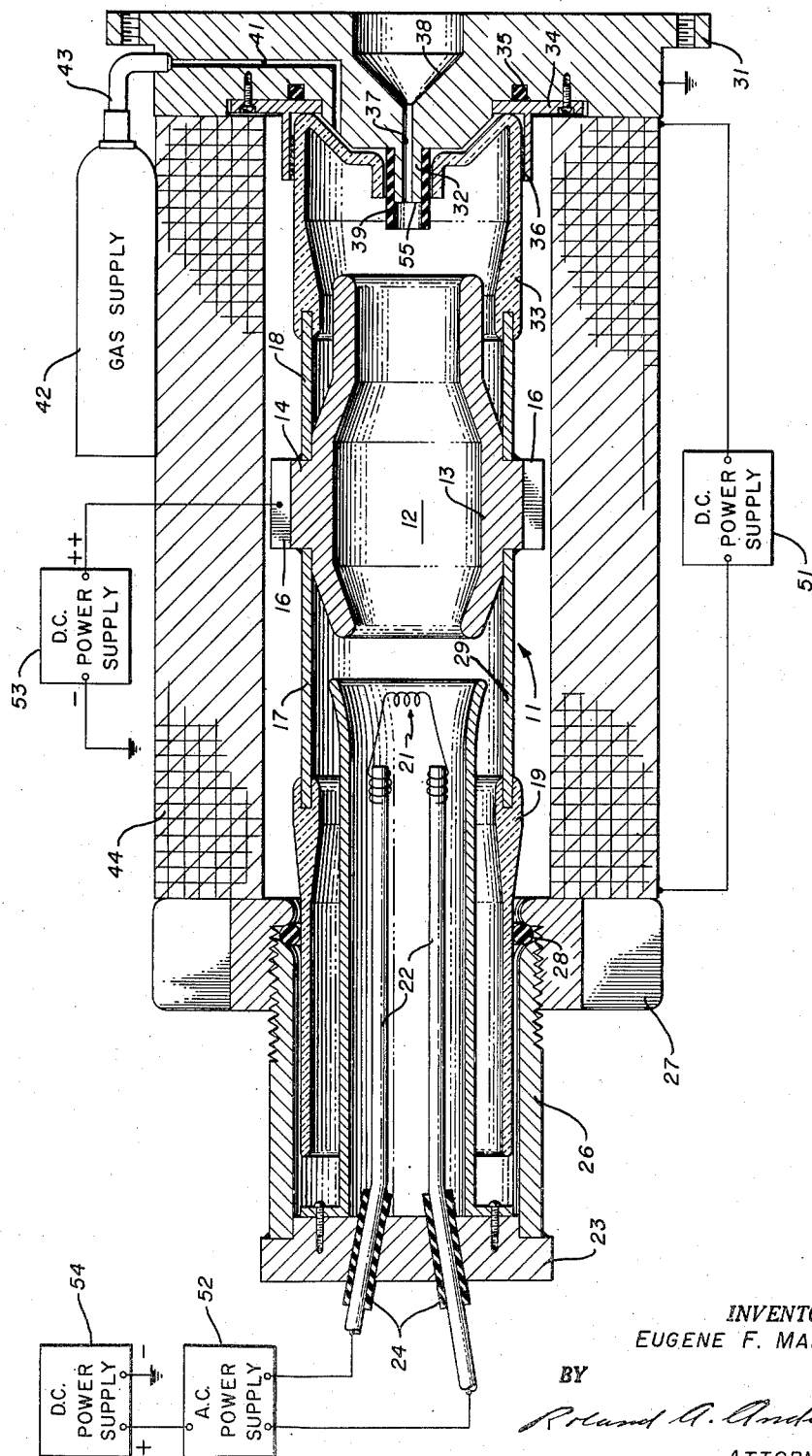
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ION SOURCE

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1

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ION SOURCE

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The present invention relates to an improved ion source particularly adapted to provide an intense beam of ions with minimum neutral molecule egress from the source.

The ion source hereinafter described employs the principle of electron oscillation or refluxing to provide elongated electron paths for maximizing ionization. To provide a large ion reservoir, there is produced an arc plasma by the aforementioned oscillating electron discharge in a gaseous atmosphere, and from this plasma is extracted an intense ion beam with a minimization of gas flow from the source.

In many ion source applications it is important to limit gas flow therefrom and one measure of ion source efficiency is the ratio of ions to un-ionized particles leaving the source. For example, in the instance where the gas to be ionized is in short supply or is of some particular value, it is advantageous to ionize all molecules leaving the source. Further, neutral molecules in an ion beam contaminate same insofar as many ion beam applications are concerned.

In addition to the feature of minimizing gas flow from an ion source the present invention is directed to the production of an intense focused ion beam. Many sources provide a large quantity of ions and yet fail to extract high current ion beams therefrom or fail to extract ions in a focused beam which may be readily employed. Difficulties of this nature arise in part from the unique properties of plasmas which, in general, are not pervious to electric fields. Previously ion extraction from a source was in large part dependent upon available electric power and ion sources have been rated in accordance with ion beam current relative to ion source energizing current. The present invention operates to increase ion beam current without the usual increase in source input current so as to be economical of construction and operation.

It is an object of the present invention to provide an improved ion source producing an intense focused ion beam of small cross section.

It is another object of the present invention to provide an improved ion source substantially eliminating gas flow therefrom.

It is a further object of the present invention to provide an improved ion source maximizing ion extraction therefrom.

It is yet another object of the present invention to provide an improved ion source producing shaped fields for ion extraction to maximize the latter.

Numerous other advantages and possible objects of the invention will become apparent to those skilled in the art from the following description of a single exemplary preferred embodiment taken together with the attached drawing wherein the sole figure is a central longitudinal section taken in the median plane of an ion source constructed in accordance with the invention.

Considering now the structural details of a preferred embodiment illustrated in the accompanying drawing, there is provided a vacuum-tight envelope 11 defining

2

therein an ionization chamber 12. An anode 13 may form a structural part of the envelope 11, as shown, and this anode has a generally hollow cylindrical configuration with a raised boss 14 about the exterior thereof and cooling fins 16 extending radially outward from this anode boss. As envelope constituents, a pair of hollow cylinders 17 and 18 abut the anode boss on opposite sides thereof and extend axially from the anode to generally encompass same. The anode is formed of metal such as copper and with metal cylinders 17 and 18, these elements may be rigidly joined by welding.

The envelope 11 further includes a cylindrical insulator 19 axially aligned with the metal cylinder 17 and sealingly connected to the outer end thereof. At this end of the source envelope there is provided a hot filament cathode 21 in the form of a coil of electron emissive wire disposed adjacent the near end of the anode cylinder and aligned with the axis thereof. The filament 21 is mounted between a pair of rigid metal rods 22 which extend beyond the end of the envelope insulator 19 and there extend through a transverse plate 23 via insulators 24. The rods 22 may be bent outward in their traverse through the plate 23 so as to maximize their separation outside the envelope for preventing electrical breakdown therebetween in air. The envelope 11 is closed and sealed at the filament end by a rigid end cylinder 26 affixed to the plate 23 in enveloping relation to the outer end of the envelope insulator and having external threads engaged by a large nut 27. Sealing results from a ring seal member 28 formed of a resilient material, for example, disposed between the end cylinder 26 and an inner boss on the nut 27 and thereby squeezed therebetween to contact the envelope insulator about the outer periphery. A heat shield 29 formed for example of a reflecting material, such as stainless steel, is disposed about the filament rods flaring outward about the filament and secured to the end plate as by bolts through a shield flange into the end plate.

At the other end of the source there is provided an end plate 31 having a substantial thickness at least at the center thereof on an axial extension of the anode. This end plate 31 is formed of metal and may have the inner side thereof stepped toward the anode with a central cylindrical boss 32 thereon. The envelope 11 is completed by an insulator 33 having a cylindrical section joined to the outer end of the envelope cylinder 18 and having a reentrant end covering the end plate 31 except for the end of the end plate boss 32. This insulator is sealed to the end plate by an annular member 34 secured as by bolts to the end plate 31 over a resilient seal 35 and having a cylindrical projection fitting about the insulating cylinder 33 and sealed thereto by a cylindrical gasket 36.

Considering further the end plate 31, there is provided therethrough a small passage 37 extending through the center of the end plate boss 32 on an extension of the axis of the anode and preferably terminating at the apex of a conical depression 38 in the outer side of the end plate. A field shaping insulator 39 is secured about the end plate boss 32 extending therefrom toward the anode a predetermined distance interiorly of the envelope insulator 33. Also, it is convenient to introduce a gas to be ionized into the envelope 11 at the end plate 31 and to this end a generally radial gas passage 41 is formed in the end plate and communicating with the envelope interior as by an opening between the field shaping insulator 39 and the envelope insulator 33. A suitable exterior gas supply 42 is connected by tubing 43 to the end plate at the gas passage 41 therein so that gas flows at a controlled rate into the envelope 11.

In addition to the foregoing elements of the invention,

there is provided magnetic field producing means which may take the form of a long solenoid 44 disposed about the envelope 11 and adapted to establish and maintain magnetic lines of force axially through the anode cylinder at least to the filament and end plate boss. It is contemplated that the present ion source shall be connected at the end plate 31 to suitable equipment for utilizing an ion beam produced by the source and that such equipment shall include evacuation means. The present source would then be evacuated through the end plate passage 37; however, separate pump-out connections may be provided as in one of the envelope cylinders or in the plate 23.

Energization of the source may be accomplished by such equipment as is shown schematically in the drawing and including a direct current power supply 51 connected across the magnet winding 44. Filament current is supplied by a power supply 52 connected between exterior ends of the filament support rods 22 and this supply may produce an alternating current output for heating the filament. Discharge within the source is accomplished by maintenance of the anode at a positive potential relative to the filament and electron oscillation or refluxing is accomplished by maintaining the end plate 31 at a negative potential relative to the anode. In the illustrated embodiment, the end plate 31 is electrically grounded while the anode is maintained at a high positive potential by connection to the positive terminal of a power supply 53 having the other terminal grounded and the filament is maintained at an intermediate positive potential by connection to the positive terminal of a power supply 54 having the other terminal grounded.

As regards operation of the ion source of the present invention, it is first noted that the end of the end plate boss 32 adjacent the anode 12 comprises a cathode 55 as well as an ion extracting electrode. Thus in operation, heating of the filament 21 by current from the power supply 52 via the filament rods 22 causes the filament to become electron emissive. There exists a potential difference between the anode 13 and filament 21 by virtue of the more positive output of the power supply 53 applied to the anode so that electrons emitted from the filament are attracted toward the anode. The magnetic field produced by the solenoid axially of the anode constrains the emitted electrons to traverse the anode so that they emerge from the opposite side of the anode generally following magnetic flux lines and approach the grounded cathode 55. The relatively negative potential of the cathode 55 repels electrons so that they return through the anode along magnetic lines of force whence they obtain elongated paths in oscillation between filament and cathode. A gaseous atmosphere maintained within the envelope from the gas supply 42 is ionized by the strong electron discharge through the anode and the probability of any single electron producing a positively charged ion from collision with a neutral gas molecule is maximized by the elongated electron path provided.

There is thus produced within the envelope a large number of ions which together with the electrons form an intense space charge neutralized plasma. This plasma which attains substantially the potential of the most positive electrode forming same, i. e., the anode, extends axially through the anode into the vicinity of the filament and cathode. It will be seen that near the filament and cathode, ions are attracted and electrons repelled to terminate the plasma thereat.

It will be appreciated that despite the presence of a strong magnetic field through the source a certain number of electrons and ions do strike the anode with a consequent heating thereof. This has proven somewhat of a problem in prior ion sources so that in the present invention the anode is cooled. The anode fins 16 ex-

tending outside the vacuum envelope radiate heat away from the anode and the heat conduction from the anode and the heat conduction from these fins may be increased by providing forced air passage thereover.

In the present invention the field about the cathode is shaped by the insulator 39 extending therefrom so that field lines extend generally normal to the cathode and axially of the anode to the insulator end where they diverge. There is thus produced a plasma meniscus about the insulator 39, i. e., a concave plasma shape surrounds the insulator end. This is highly advantageous for ions are attracted generally along the electric field lines and thus ions leaving the plasma at the cathode end are focused toward the passage 37 for traverse there-through in a pencil beam. It is further to be appreciated that the filament and cathode are not maintained at the same potential so that ion preferentially leave the plasma at the cathode end and fall through a greater potential thereat than would they at the filament end of the plasma.

As regards the conservation of gas within the source or the prevention of escape of un-ionized gas the plasma configuration is seen to somewhat envelope the open end of the insulator about the cathode. Thus any un-ionized gas particles tending to drift into the cathode insulator would generally enter the plasma whereat moving ions and electrons would probably ionize same by collision. A further provision for minimizing escape of un-ionized molecules is the configuration of the ion egress passage 37. As previously noted, this passage 37 is made quite long with a small cross section and this is herein possible without undue ion loss to the walls thereof by the ion focusing action provided adjacent plasma end. With an intense well focused ion beam traversing the passage and substantially filling same any un-ionized molecule drifting therein must pass through the ion beam and is therein ionized by collision. Consequently, the probability of un-ionized gas molecules leaving the chamber 12 through the passage 37 is quite remote and substantially only a beam of ions is passed therethrough and ejected from the source.

What is claimed is:

1. An ion source comprising means including an anode and cathode establishing an oscillating electron discharge with a cathode at one end thereof, and said end cathode defining an elongated ion egress aperture therethrough, means supplying a gas to be ionized to said discharge for producing a plasma, and electric-field shaping means extending from said end cathode toward said plasma for forming a dished plasma end adjacent said cathode.

2. An ion source comprising means including an anode and cathode establishing an oscillating electron discharge, an electrode adapted to be maintained at a negative potential relative to said anode and disposed at an end of said discharge, said electrode having an ion egress aperture therethrough, means supplying gas to said discharge for producing a plasma therefrom, and a cylindrical insulator having a lesser diameter than said plasma extending from said electrode about the aperture therein toward said plasma for focusing ions from said plasma into said ion egress aperture.

3. An ion source comprising a hollow anode, means establishing a magnetic field through said anode, a heated filament adjacent one end of said anode, an apertured electrode disposed adjacent the other end of said anode and with said filament maintained at a negative potential relative to said anode whereby electrons emitted from said filament oscillate through said anode, means supplying gas to said discharge for producing a plasma through said anode, and means electrically masking said electrode except a small portion about the aperture therein for shaping the adjacent plasma end to focus ions into the electrode aperture.

4. An ion source comprising a cylindrical anode, a heated filament disposed adjacent one end of said anode

5

for emitting electrons that are attracted by said anode, means establishing a magnetic field through said anode constraining electrons to pass therethrough, an electrode having a small surface exposed adjacent the opposite end of said anode from said filament and defining an ion egress aperture therein, and means maintaining said electrode at a negative potential relative to said anode and to said filament whereby electrons are repelled from said electrode back through said anode, and means providing a gas to said discharge for producing a plasma through said anode whereby ions from said plasma are accelerated through said electrode aperture in a beam.

5. An ion source comprising an evacuated envelope including an end insulator, a cylindrical anode disposed within said envelope, a heated filament disposed within said envelope adjacent one end of said anode and maintained at a negative potential with respect thereto whereby electrons are attracted therefrom, means establishing a magnetic field through said envelope axially of said anode whereby said electrons discharge through said anode, means introducing gas into said envelope for producing a plasma therein through said anode, and an electrode maintained at a negative potential relative to

6

said anode and filament disposed on the opposite side of said anode from said filament and having a small central aperture therethrough, the end insulator of said envelope covering all of said electrode except a small area about the aperture therethrough whereby the plasma is terminated adjacent said electrode area and ions focused therefrom through said electrode aperture.

6. An ion source as claimed in claim 5 further defined by a cylindrical insulator disposed about said exposed electrode area and extending therefrom toward said plasma and thereby shaping the electric field about said electrode to focus ions from said plasma through said electrode aperture.

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