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[54] **MULTIPACTOR ION GENERATOR**

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[52] **U.S. Cl.** **315/111,** 313/63, 313/103, 313/230

[51] **Int. Cl.** **H01j 7/24**

[58] **Field of Search** 315/111; 313/103, 63, 230, 313/106

[56] **References Cited**

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[57] **ABSTRACT**

An electrostatic, transverse axis, multipactor ion gun having an anode in the form of a helically coiled element defining a cylinder having an axis, the turns of the anode element being axially spaced-apart to provide an open anode structure. An elongated dynode sleeve concentrically surrounds the anode, being radially spaced therefrom, the interior surface of the dynode sleeve having secondary emissive properties. The anode and dynode sleeve are supported within the first section of an enclosing envelope which has a gas inlet therein for admitting ionizable gas at an ionizing pressure thereto. An elongated accelerating electrode sleeve is provided supported within a second section of the envelope and coaxial with the axis, the accelerating electrode sleeve being axially spaced from the anode and dynode sleeve. The second envelope section has a coaxial opening therein through which the ions which are generated by the gun axially flow. Progressively lower direct current potentials are applied to the anode, dynode sleeve and accelerating electrode so as to cause circulatory electron flow within the dynode sleeve through the anode generally transverse to the axis, such circulatory electron flow causing generation of ions in the region of the axis which are caused to flow axially toward and through the envelope opening by the accelerating electrode. The interior surface of the dynode sleeve is formed as a plurality of axially extending, abutting segments which are triangular in cross-section, and which have their apices extending radially outwardly with respect to the axis, so that a preponderance of the electrons which flow through the anode bypass the region immediately surrounding the axis, thereby reducing losses due to recombination of ions and electrons.

13 Claims, 2 Drawing Figures

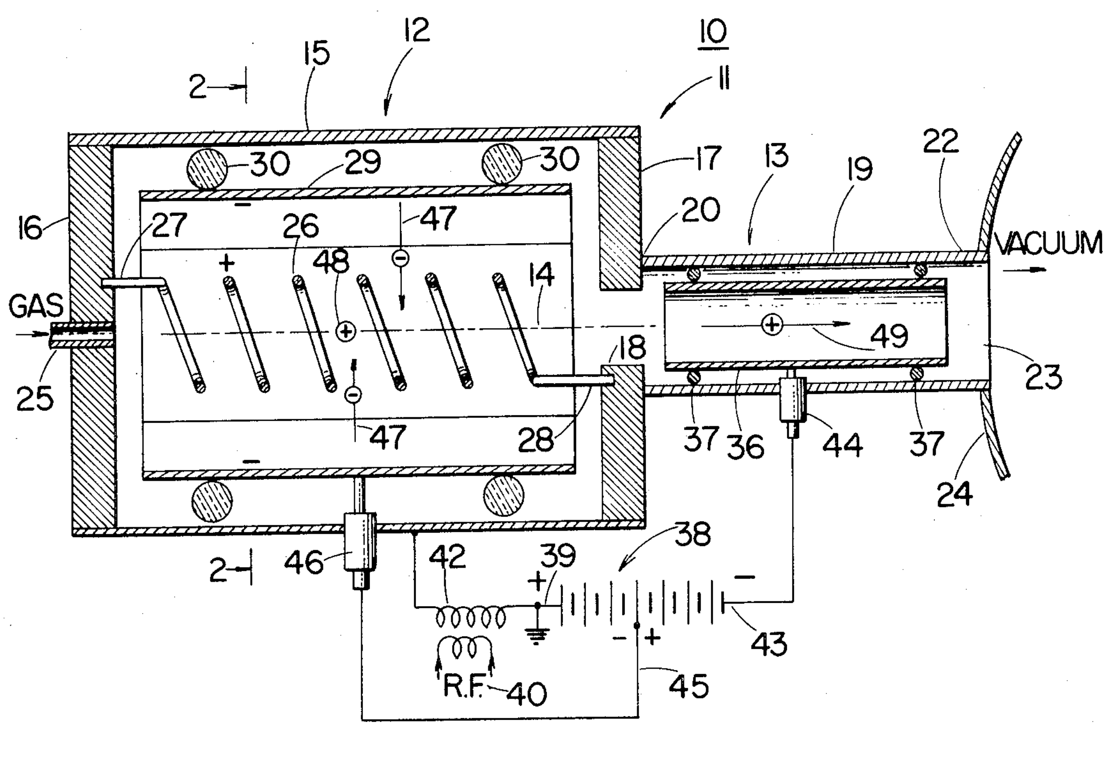


FIG. 1

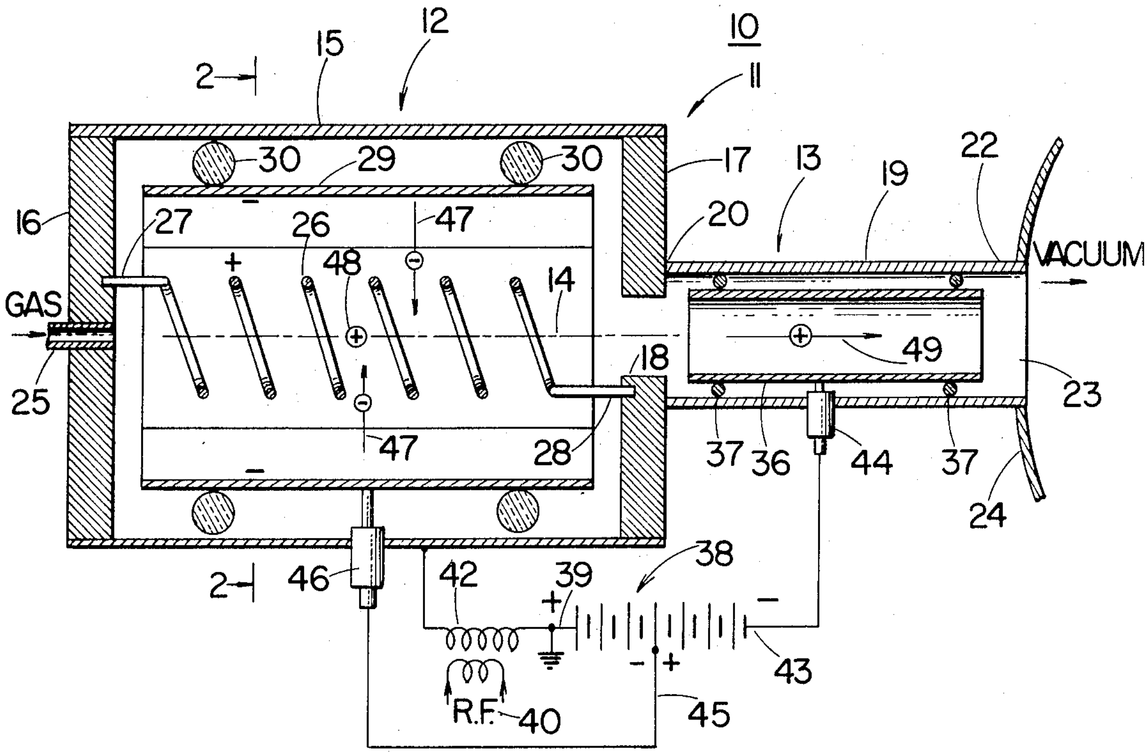
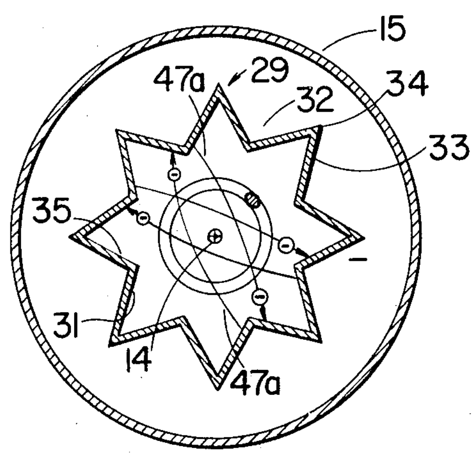


FIG. 2



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MULTIPACTOR ION GENERATOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to multipactor ion generators, and more particularly to an electrostatic, transverse axis, multipactor ion gun.

2. Description of the Prior Art

Farnsworth U.S. Pat. Nos. 3,181,028 and 3,240,421 disclose multipactor ion generators employed in ion transport vacuum pumps. Farnsworth U.S. Pat. No. 3,386,883 discloses an ion gun employed in nuclear fusion apparatus and using a thermionic cathode as an electron source. Farnsworth U.S. Pat. No. 3,201,640 discloses a multipactor electron gun employed in a cathode ray tube. Application Ser. No. 797,473 filed Feb. 7, 1969, of Gene Meeks, discloses an electrostatic transverse axis multipactor ion generator employed as an oscillator. All of said Farnsworth patents and said Meek application are assigned to the assignee of the present application.

In general, all ion guns require an efficient means of ionization and extraction of the ions. Multipactor ion generators of the type shown in the aforesaid Farnsworth patents and Meek application include opposed dynode surfaces which have secondary emissive properties, with an open anode structure therebetween. An ionizable gas, such as deuterium, under an ionizable pressure is admitted to the enclosing envelope. The application of appropriate direct current potentials, with a radio frequency potential superimposed thereon, causes a circulatory flow of ionizing electrons between the dynode surfaces, the electrons being caused repeatedly to strike the dynode surfaces with sufficient velocity to release secondary electrons therefrom, the resultant circulatory electron flow being limited by space charge saturation. Relatively efficient ionization results, as shown by the fact that such devices may be operated with gas pressure in the range of 10^{-3} to 10^{-6} mm where relatively few gas molecules are available for ionization.

One of the problems encountered in the design of multipactor ion generators is the difficulty of initially generating ion flow. The process of electron build-up depends upon some few electrons being present at the right time in the applied radio frequency cycle. Efforts to minimize this problem have included the use of an applied radio frequency potential of many hundreds of volts, the application of an initial "shock" voltage, the use of electron multiplication surfaces having a high secondary emitting ratio, and the use of a "field emitter point," i.e., a sharp point with a corresponding high electric field in front of it to produce a stream of electrons to initiate the electron build-up process. A series resistance is required in the point circuit in order to prevent destruction of the point. Other proposals to furnish electrons for the initial starting process include the use of tritium or some other beta emitter absorbed on the walls of the tube which will steadily emit a few electrons. Further, a typical thermionic cathode may be employed for starting purposes.

In the device of the aforesaid Meeks application, a cylindrical dynode sleeve coaxially surrounds an open anode structure with the circulatory electron flow thus taking place across the structure transversely of the cylindrical axis. With employment of a cylindrical

dynode sleeve, the ions tend to collect in a line on the axis, this line also being the focal cross-over point for the electrons flowing back and forth between diametrically opposite points on the cylindrical dynode sleeve, recombination losses thus occurring due to recombination of some of the electrons and ions.

SUMMARY OF THE INVENTION

In accordance with the invention, an ion generator of the general type shown in the aforesaid Meeks application is provided with the anode sleeve having undulations therein so that a preponderance of the electrons flowing between opposite points on the dynode sleeve surface and through the anode bypass the region immediately surrounding the axis, thereby avoiding electron cross-over at the axis and minimizing recombination losses. Provision of the undulations, which in the specific embodiment take the form of a plurality of axially extending, abutting segments which, in cross-section, comprise triangles having their apices extending radially outwardly with respect to the axis, further aids in insuring rapid starting of the device.

In accordance with the broader aspects of the invention, there is provided an electron discharge device having an elongated anode defining a cylinder having an axis, the anode being permeable to the flow of charged particles therethrough in directions generally transverse to the axis. An elongated dynode sleeve is provided concentrically surrounding the anode and radially spaced therefrom, the interior surface of the dynode sleeve having secondary emissive properties. Means for energizing the anode and dynode sleeve are provided thereby to cause circulatory electron flow within the dynode sleeve through the anode generally transverse to the axis. The interior surface of the dynode sleeve has undulations formed therein so that a preponderance of electrons flowing through the anode bypass the region immediately surrounding the axis.

It is accordingly an object of this invention to provide an improved multipactor device.

Another object of the invention is to provide an improved multipactor ion generator.

A further object of the invention is to provide an improved multipactor ion generator of the electrostatic, transverse axis type, wherein recombination of circulatory electrons and ions is minimized.

A still further object of the invention is to provide an improved electrostatic, transverse axis, multipactor ion gun.

The above-mentioned and other features and objects of this invention and the manner of attaining them will become more apparent and the invention itself will be best understood by reference to the following description of an embodiment of the invention taken in conjunction with the accompanying drawings, wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side cross-sectional view showing the improved multipactor ion gun of the invention; and

FIG. 2 is a cross-sectional view taken generally along the line 2—2 of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the figures of the drawings, the improved electrostatic, transverse axis, multipactor ion gun of the invention, generally indicated at 10, comprises an enclosing envelope 11 having first and second cylindrical sections 12 and 13 coaxial with axis 14. Envelope section 12 includes a cylindrical wall 15 with opposite end walls 16 and 17 sealed thereto. An opening 18 is formed in end wall 17 through which axis 14 extends. Envelope section 13 comprises a cylindrical wall 19 having its end 20 sealed to wall 17 of envelop section 12 and communicating with opening 18. The other end 22 of cylindrical wall 19 is open, as at 23, and is secured to a wall 24 of utilization apparatus, such as a vacuum pump where the gun 10 is employed for ion transport purposes, or the anode 20 of the nuclear fusion apparatus disclosed in the aforesaid Farnsworth U.S. Pat. No. 3,386,883. It will be understood that a vacuum exists in the chamber of which the wall 24 forms a part. A gas inlet conduit 25 communicates with the interior of envelope section 12, as by extending through end wall 16, for admitting the ionizable gas thereto.

Walls 15, 16, 17 and 19 of envelope 11 may be formed of suitable metal, such as steel, with the walls being sealingly joined, as by welding.

A helically coiled anode element 26 is disposed within envelope section 12, coaxial with axis 14, and having its opposite ends 27, 28 respectively secured to end walls 16, 17, as shown. The turns of the coiled anode element 26 are axially spaced apart, as shown, thereby providing an essentially open anode structure having about 90 percent transmission.

An axially extending dynode sleeve 29 is provided within envelope section 12 coaxially surrounding anode 26 and supported on cylindrical wall 15 by annular insulators 30, as shown.

Referring particularly to FIG. 2, dynode sleeve 29 has a plurality of axially extending undulations 32 formed therein, undulations 32 being formed as a plurality of abutting, axially extending segments each comprising, in cross-section, a triangle 33 having its apex 34 extending radially outwardly with respect to axis 14 toward the cylindrical wall 15. Resultantly, corresponding axially extending, triangular segments 31 are provided having their apices 35 extending radially inwardly toward axis 14.

In a specific embodiment of the invention, dynode sleeve 29 was formed of aluminum having its interior surface coated with secondary emissive material, such as magnesium oxide.

An axially extending accelerating electrode sleeve 36 is provided coaxial with axis 14 within cylindrical wall 19 of envelope section 13, being supported thereon by means of annular insulating supports 37.

A suitable source of direct current potential, schematically shown as battery 38, is provided having its positive terminal 39 connected to the metallic envelope 11 and thus to the opposite ends 27, 28 of anode 26. Positive end 39 of direct current source 38 is preferably grounded, as shown. A suitable source of radio frequency 40 is inductively coupled to anode 26 by induction coil 42 coupled in series between envelope 12 and positive end 39 of direct current source 38, thus superimposing a radio frequency potential on the direct current potential applied between anode 26 and dynode sleeve 29. The negative end 43 of direct current source 38 is coupled to the accelerator electrode 36 by a suitable stand-off insulator 44 extending through wall 19. An intermediate potential point 45 on direct current source 38 is coupled to anode sleeve 29 by a suitable stand-off insulator 46 which extends through wall 15. It will thus be seen that progressively lower direct current potentials are applied to anode 26, dynode sleeve 29 and accelerating electrode 36, a radio frequency potential being superimposed on the direct current potential applied between anode 26 and dynode sleeve 29.

Considering now that a source of ionizable gas, such as deuterium, at a pressure in the range of about 10^{-3} to about 10^{-6} mm, is coupled to conduit 25, and that the appropriate direct current and radio frequency potentials are applied, as above-described, whatever free electrons are present within envelope section 12 will be accelerated from dynode sleeve 29 radially toward anode 26, as shown by the arrows 47, these electrons passing through the open anode 26 and striking the secondary emissive interior surface of dynode sleeve 29 on the opposite side thereof with sufficient velocity to cause the emission of additional secondary electrons, which are then accelerated in the reverse direction toward and through anode 26. Resultantly, a cloud of circulatory electrons is rapidly produced traversing dynode sleeve 29 through anode 26 transversely of axis 14. Some of these circulatory electrons collide with gas molecules resulting in ionization of the same thereby providing further electrons which become a part of the circulatory flow of electrons, and ions which tend to collect on the center line 14, as shown at 48. The negative potential applied to the accelerating electrode sleeve 36 causes movement of the ions along axis 14 through opening 18 and end wall 17, through accelerating electrode sleeve 36, and through open end 23 of envelope section 13, as shown by the arrow 49.

Referring now specifically to FIG. 2, it will be observed that the electrostatic field at the interior surface of dynode sleeve 29 is not directed toward the axis 14. Resultantly a preponderance of the circulatory electrons flowing through anode 26 bypass the region immediately surrounding axis 14, as shown at 47a in FIG. 2, thus bypassing the volume of high density ions which are slowly drifting along axis 14 toward the extraction opening 18.

It will now be seen that by providing the interior surfaces of dynode sleeve 29 with undulations or scallops, as shown, the focal cross-over point for the bulk of the circulatory electrons is not coincident with the axis 14, and thus that the possibility of gas ions which are drifting along the axis 14 recombining with circulatory electrons is minimized. Thus, with the undulated or scalloped configuration of the dynode sleeve, recombination losses are reduced. Further, the undulated or scalloped configuration of the dynode sleeve 29 provides faster starting of the device.

The outside diameter of the anode element 26 is preferably in the range from about one-third to one-half the outside diameter of the dynode sleeve 29, as defined by the outer apices 34.

In a specific embodiment of the device shown in FIGS. **1** and **2** and above-described, dynode sleeve **29** has an axial length of 1½ inches, eight axially extending triangular segments **33**, an outside diameter of 1⅛ inches, and an inside diameter of three-fourths inch. Anode **26** had an axial length of 1½ inches, an outside diameter of one-half inch, and an axial spacing between turns of one-sixteenth inch. Accelerator sleeve **36** had an axial length of seven-eighths inch and an inside diameter of three-eighths inch. Direct current power source **38** provided a total voltage of about 2 kilovolts between positive and negative ends **39** and **43**, with intermediate potential point **45** being about 1 kilovolt. Radio frequency source **40** had a frequency of 2 megahertz and the radio frequency voltage superimposed upon the direct current voltage applied across anode **26** and dynode sleeve **29** was about 1,000 volts RMS.

It will be observed that the transverse axis multipactor ion gun illustrated in FIGS. **1** and **2** and above-described is of the electrostatic type, i.e., no magnetic field is provided for concentrating the ions in the region of axis **14** and for moving the ions axially through the extraction opening **18**.

While there have been described above the principles of this invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of the invention.

What is claimed is:

1. In an electron discharge device, an elongated anode defining a cylinder having an axis, said anode being permeable to the flow of charged particles therethrough in directions generally transverse to said axis, an elongated dynode sleeve concentrically surrounding said anode and radially spaced therefrom, the interior surface of said dynode sleeve having secondary emissive properties, and means for energizing said anode and dynode sleeve thereby to cause circulatory electron flow within said dynode sleeve through said anode generally transverse to said axis, said interior surface of said dynode sleeve having undulations therein so that a preponderance of the electrons flowing through said anode bypass the region immediately surrounding said axis.

2. The device of claim **1** wherein said undulations extend axially throughout the length of said dynode sleeve.

3. The device of claim **2** wherein said undulations, in cross-section, comprise a plurality of abutting triangular segments having their apices extending radially outwardly with respect to said axis.

4. The device of claim **1** wherein said anode comprises a helically coiled element having its turns axially spaced apart.

5. The device of claim **1** further comprising an envelope enclosing said dynode sleeve and anode, said dynode sleeve and anode being supported by said envelope.

6. The device of claim **1** wherein said envelope contains an ionizable gas at an ionizing pressure so that said circulatory electron flow causes generation of ions in said region, whereby said device functions as an ion generator.

7. The apparatus of claim **6** wherein said energizing means includes means for applying progressively lower direct current potentials to said anode and dynode sleeve, and means for superimposing a radio frequency potential on one of said direct current potentials, whereby said device functions as a multipactor.

8. The device of claim **6** further comprising means for admitting said gas to the interior of said envelope.

9. The device of claim **8** wherein said envelope has an opening therein through which said axis extends, said energizing means including second means for causing said ions to flow axially outwardly through said opening, whereby said device functions as an ion gun.

10. The device of claim **9** wherein said second means includes an accelerating electrode in said envelope coaxial with said axis, said energizing means including means for applying progressively lower potentials to said anode, dynode sleeve and accelerating electrode.

11. The device of claim **10** wherein said accelerating electrode comprises a second elongated sleeve, said envelope comprising a first portion which encloses said anode and dynode sleeve, and a second portion which encloses and supports said second sleeve, and further comprising a partition between said envelope portions and having an opening therein through which said axis extends and through which said ions flow toward said second sleeve.

12. The device of claim **11** wherein said undulations extend axially throughout the length of said dynode sleeve, said undulations, in cross-section, comprising a plurality of abutting triangular sections having their apices extending radially outwardly with respect to said axis, said energizing means including means for applying direct current potentials to said anode, dynode sleeve and accelerating electrode, and means for superimposing a radio frequency potential on one of the direct current potentials applied to said anode and dynode sleeve, whereby said device functions as a multipactor.

13. The device of claim **12** wherein said anode comprises a helically coiled element having its turns axially spaced apart, the outside diameter of said element being less than one-half the outside diameter of said dynode sleeve as defined by said apices.

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