# United States Patent [19]

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[54] **ION SOURCES**


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[51] **Int. Cl.** ..... **H01g 17/16**

[58] **Field of Search** ..... 313/63, 188; 250/427



[56] **References Cited**

UNITED STATES PATENTS

3,484,602 12/1969 McIlraith ..... 250/41.9



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[57] **ABSTRACT**

An ion source comprising a right-circular cylindrical cathode having two anode rods extending through the cylinder and symmetrically disposed about its axis. An ion beam outlet aperture is formed in the cylindrical wall of the cathode, and an inlet is provided in the cathode for introducing a gas therein.


**13 Claims, 2 Drawing Figures**

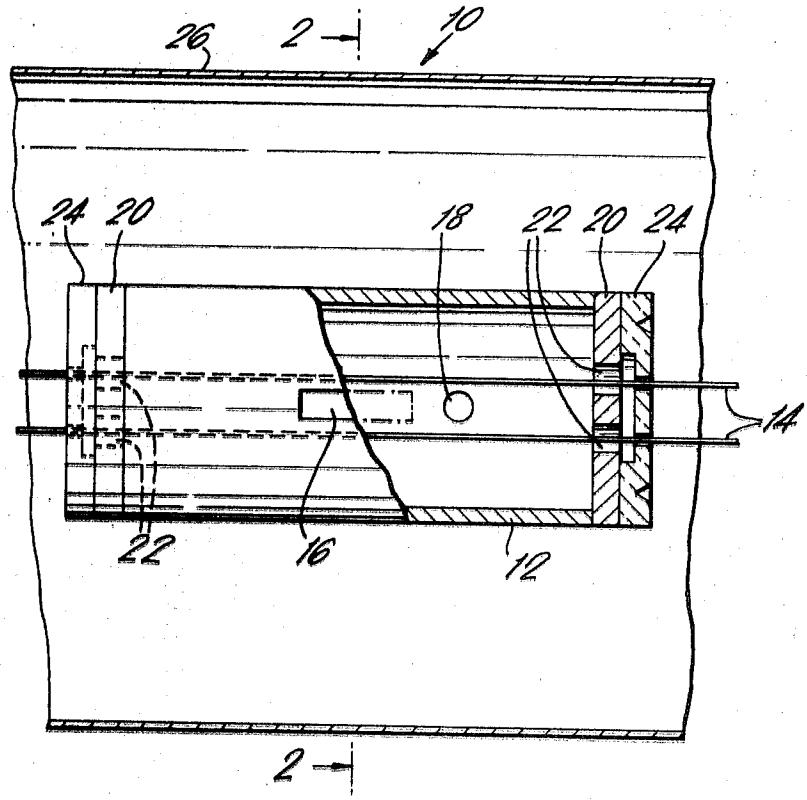


FIG. 1

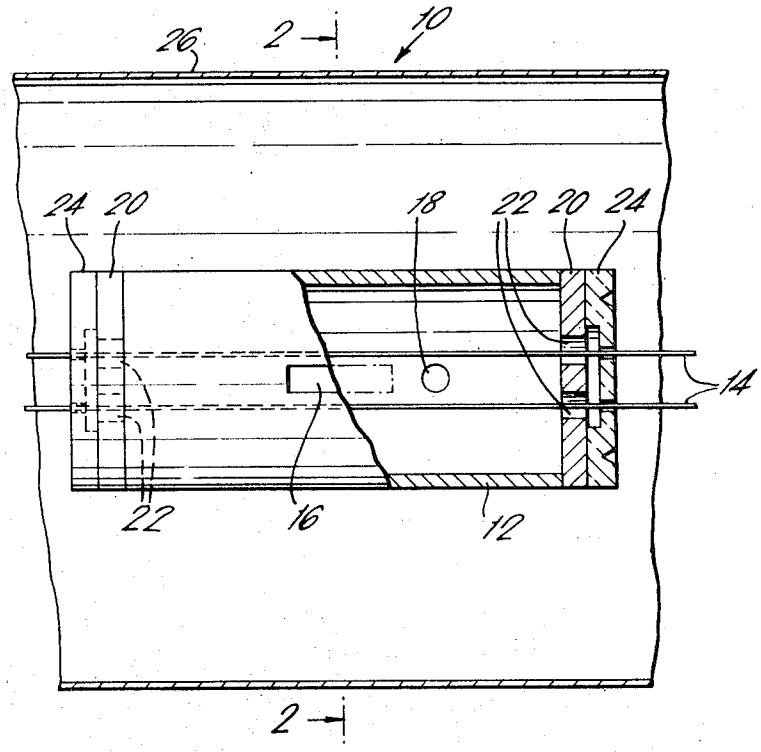
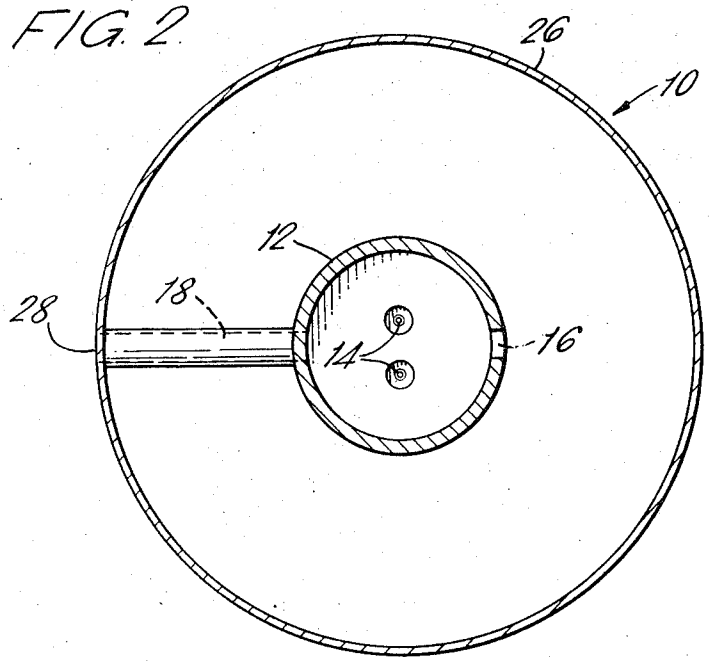



FIG. 2



# ION SOURCES

The present invention relates to ion sources and concerns ion sources suitable for use, inter alia, in charged particle oscillators of the kind described in the specification of British Letters Pat. No. 1,158,782 (U.S. Pat. No. 3,484,602).

In the above-mentioned specification there is described a charged particle oscillator comprising a cylindrical cathode encompassing two anodes symmetrically disposed about the axis of the cylinder. In such an arrangement an electron starting from rest follows a relatively long oscillatory path such as to create a fairly large number of ions before being brought to a standstill on one of the anodes.

It has been proposed to make use of such an arrangement for controlling the removal of, for example, material from solid surfaces; and in this connection there is described a device in J. Phys. D: Applied Physics Volume 3 (1970) at pages 1399 to 1402. As described in this last mentioned reference if gas at low pressure is introduced into a vacuum chamber in which a charged particle oscillator of the kind above referred to is located, then the probability of ionisation becomes high because the electron paths become longer than the dimensions of the cathode. The positive ions thus produced are accelerated towards the cathode and will only be usefully produced in the region where long oscillatory paths are followed and thus the cathode will only be bombarded in certain regions. As described in such reference, if an aperture is formed in the cathode in one of those regions a beam of ions will emerge therefrom and may be collected in, for example, a Faraday cage.

In one form as described in the last mentioned reference, the source comprises a cylindrical cathode surrounding two anode rods symmetrically disposed about the cylinder axis. An electron starting from rest within a specified region follows a long oscillatory path between the anode rods, thus creating ions in the residual gas before being brought to rest on one or other of the anode rods. When operated as a cold cathode device, the gas discharge formed is concentrated about the axial plane normal to the plane of the rods.

The gas discharge is maintained by ions bombarding the cylinder wall, thus producing further electrons. The bombarded regions of the cylinder are situated in the two areas where the gas discharge sectors intersect the wall of the cathode cylinder. The areas extend as two substantially parallel strips along most of the length of the cylinder on opposite sides of the diametrical plane normal to the plane of the anode rods. The strips terminate before reaching the ends of the cylinder because here the field is largely directed parallel to the axis of the cylinder instead of radially, in order to prevent electrons from drifting out of the tube. The cylinder is provided with end caps at cathode potential to prevent such drifting. An ion beam emerges from the aperture if the latter is located in the region of a strip. The aperture may be small or may extend along the length of the strip but as the aperture is increased in length the operating voltage and/or pressure must be increased to maintain the same ion beam density because the aperture perturbs the field and reduces the area from which electrons are produced to maintain the discharge. With a small aperture, however, the beam current is limited by the geometry of the system. The ratio of the beam current and the total cylinder current will approximate to the ratio of the area of the aperture and that of the strip regions of the cylinder wall.



The operating range of such device is limited to below the values of voltage and pressure which cause a general discharge outside the source. The operating range limit defines the output limit from the source as the output generally increases with voltage and pressure.

I have observed that such a device has a relatively limited operating range and it is therefore an object of the present invention to provide an improved device whereby the operating range is increased.

According to the invention there is provided an ion source comprising a hollow cathode including an ion beam outlet aperture in a wall thereof, $2n$ anodes symmetrically disposed about the axis of the cylinder, where $n$ is an integer and means for coupling the cathode and the anodes to a source of electric potential for the ion source, the cathode further including an inlet for introducing a gas into the cathode. Thus, in use, the field between the anodes and the cathode produces a saddle configuration between the anodes.

Preferably, the cathode is a hollow cylinder and the ion beam outlet aperture is in the cylindrical wall thereof.

The invention will now be described, solely by way of example with reference to the accompanying drawings, in which:

FIG. 1 is a side view partly in cross-section of one embodiment of an ion source according to the invention; and

FIG. 2 is an end cross-sectional view of the source of FIG. 1 taken on the line 2—2.

Referring to the drawings, there is shown an ion source **10** comprising a hollow right-circular cylindrical cathode **12** about 50 millimetres in length and 25 millimetres in diameter. The cylinder **12** is made of stainless steel. Axially arranged in the cylinder **12** are two tungsten anode rods **14**, each being approximately 1 millimetre in diameter, being disposed symmetrically about the axis of the cylinder **12** and spaced apart-by some 6 millimetres. In use, the anodes are maintained at a common potential, positive with respect to the cathode, and the resulting electrostatic field produces a saddle configuration between the anodes. An elongate aperture **16** is provided in the cathode cylinder **12**, this aperture being just over 10 millimetres in length (i.e., measured axially of the cylinder) and 2.5 millimetres high. In the area diametrically opposite to the aperture **16** but displaced axially therefrom there is provided a small inlet orifice **18** in the wall of the cylinder **12** through which gas may be passed into the interior thereof. The cylinder **12** is provided with end plates **20** at cathode potential to prevent electrons drifting axially out of the cylinder. The anode rods **14** pass through apertures **22** in the end plates **18** and are mainteined in position about the axis of the cylinder in apertures formed in ceramic insulator plates **24** mounted on the plates **20.** The apertures in the insulator plates **24** are so dimensioned that they allow expansion of the rods **14** without causing substantial stress therein. The cylinder **12** is located in an evacuated chamber **26** and a suitable gas is fed directly into the cylinder by way of an inlet **28** in the chamber **26** which is coupled to the inlet orifice **18** in the cylinder. This gas will pass

through the gas inlet orifice **18** into the interior of the cylinder and exit therefrom through the aperture **16.**

An ion source **10** as described, but constructed without the gas inlet orifice **18** so that the gas (such as argon) is fed into the vacuum chamber **26** and thence into the source **10** through the beam exit aperture **16,** gave an ion beam output of about 120 $\mu$A at about 6kv, such current being about 7.5 percent of the total tube current drawn by the source. If instead the gas is fed directly into the tube through the orifice **18** the beam current increases to about 1.2 mA, such current being about 22 percent of the tube current. In addition, by using a gas inlet orifice it has been found possible to reduce the physical size of the ion source, for example it has been found possible to reduce the length and diameter of a typical source by a factor of about 3.

It is to be appreciated that the essence of my invention is the use of a gas inlet orifice **18** in the cathode and depending on the size of the aperture **16** and the geometry of the source **10** the pressure within the cylinder **12** will always exceed the pressure in the evacuation chamber. Indeed it may exceed it substantially so that under such conditions the source can operate stably over an extended range of pressure and voltage. Without such a gas inlet orifice the output of such an arrangement is markedly less. This can be appreciated from an inspection of a cylinder which has been in use since in the case of a cylinder without a gas inlet orifice, internal discoloration will show that ionic bombardment consists of parallel strips. In the case of a cylinder with an orifice internal discoloration shows that the bombardment area becomes concentrated about the ion beam exit aperture. This effect becomes more marked as the length of the slot is decreased with respect to the axial length of the cylinder.

As above referred to the gas inlet orifice is preferably not directly opposite the apertues **16** since I have found that if the orifice is directly opposite the aperture in the described embodiment, operation tends to become less steady and the output falls somewhat.

While a source has been described having an elongate aperture **16** other shapes are possible.

Although the invention has been described with reference to a right-circular cylindrical cathode, the shape of the cathode may take a variety of different forms, such as a box-like or a spherical shape. Likewise the anodes may take suitable shapes other than as described.

I claim:

**1.** An ion source comprising a hollow cathode having a wall, the wall having an ion beam outlet aperture formed therein, $2n$ anodes in the cylinder and symmetrically disposed about the axis thereof where $n$ is an integer, means for coupling the cathode and the anodes to a source of an electric potential for the ion source, the cathode further including inlet means for introducing a gas into the cylinder.

**2.** An ion source according to claim **1,** wherein said gas inlet means is provided in said cathode substantially opposite said outlet aperture and axially displaced therefrom.

**3.** An ion source according to claim **1,** wherein the cathode is cylindrical and the said wall is the cylindrical wall thereof.

**4.** An ion source according to claim **3,** wherein said gas inlet means is provided in said cylindrical wall of said cathode substantially opposite said outlet aperture and axially displaced therefrom.

**5.** An ion source according to claim **2,** wherein said anodes are in the form of elongate rods.

**6.** An ion source according to claim **5,** wherein there are two anode rods.

**7.** An ion source according to claim **6,** wherein said outlet aperture is formed about a plane substantially normal to the plane of the anode rods.

**8.** An ion source according to claim **5,** wherein said outlet aperture is an elongate slot.

**9.** An ion source according to claim **7,** further comprising two caps mounted on the ends of said cylinder and electrically coupled thereto, said end caps having apertures formed therein through which the anodes protrude.

**10.** An ion source according to claim **9,** further comprising two plates of insulating material mounted on and externally of said two end caps respectively, said insulating means providing a means for maintaining the anode rods in position.

**11.** An ion source according to claim **10,** further comprising a chamber, means for mounting the source in the chamber, evacuating means, and means for coupling the chamber to the evacuating means.

**12.** An ion source according to claim **11,** wherein said chamber comprises an inlet and means are provided for coupling said inlet to said gas inlet means in said cylinder.

**13.** An ion source according to claim **12,** wherein said outlet aperture is an elongate slot.

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