

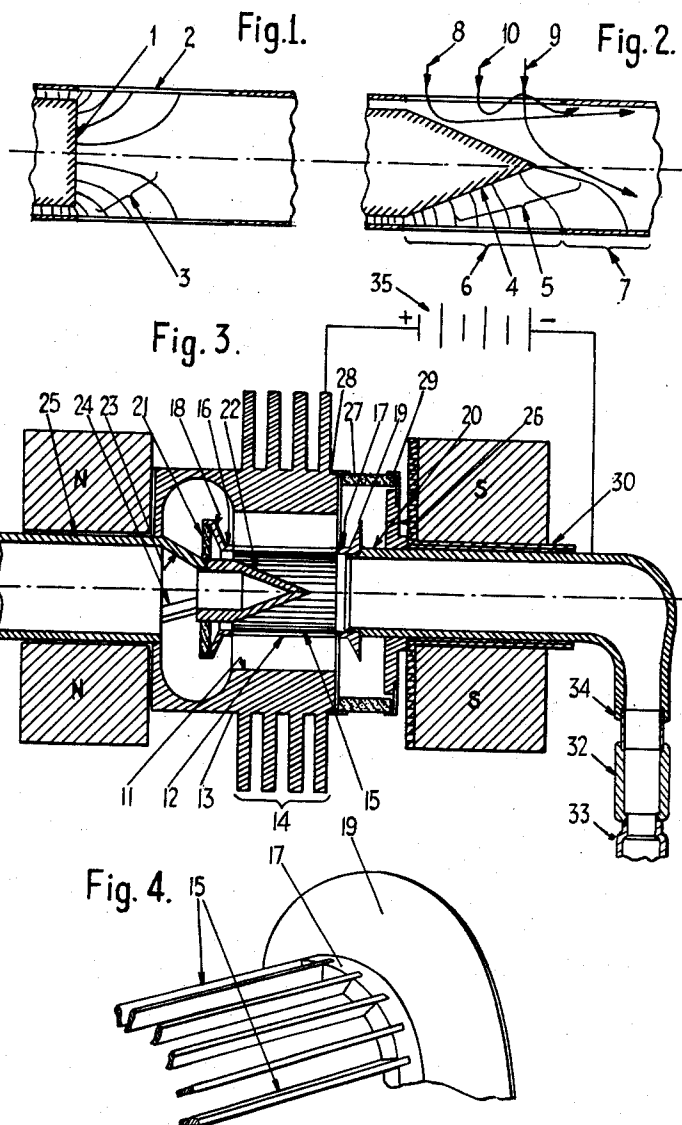
March 12, 1963

E. ROSTAS
ION PUMPS

3,081,020

Filed Feb. 6, 1959

2 Sheets-Sheet 1



Inventor
Ernest Rostas.
By
Stone & Mack
Attorneys.

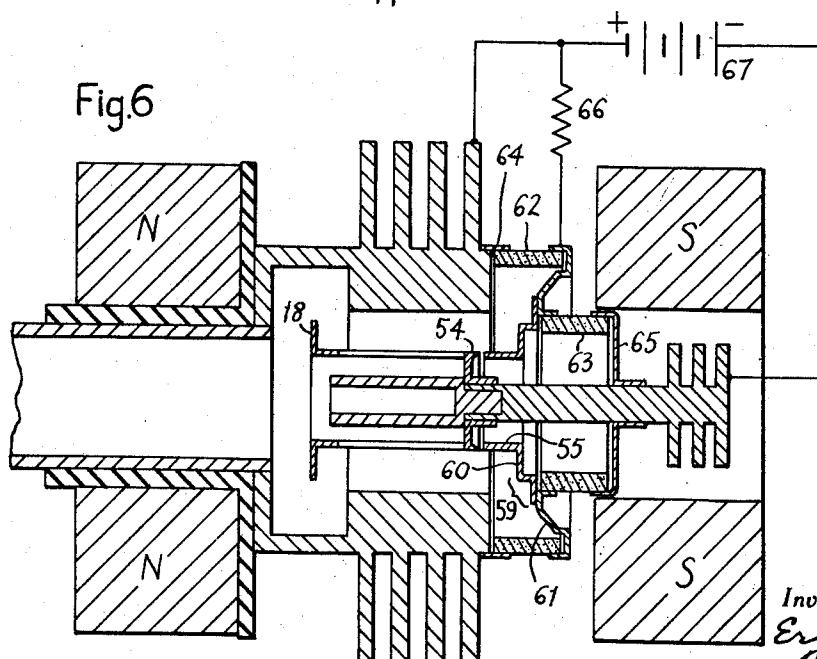
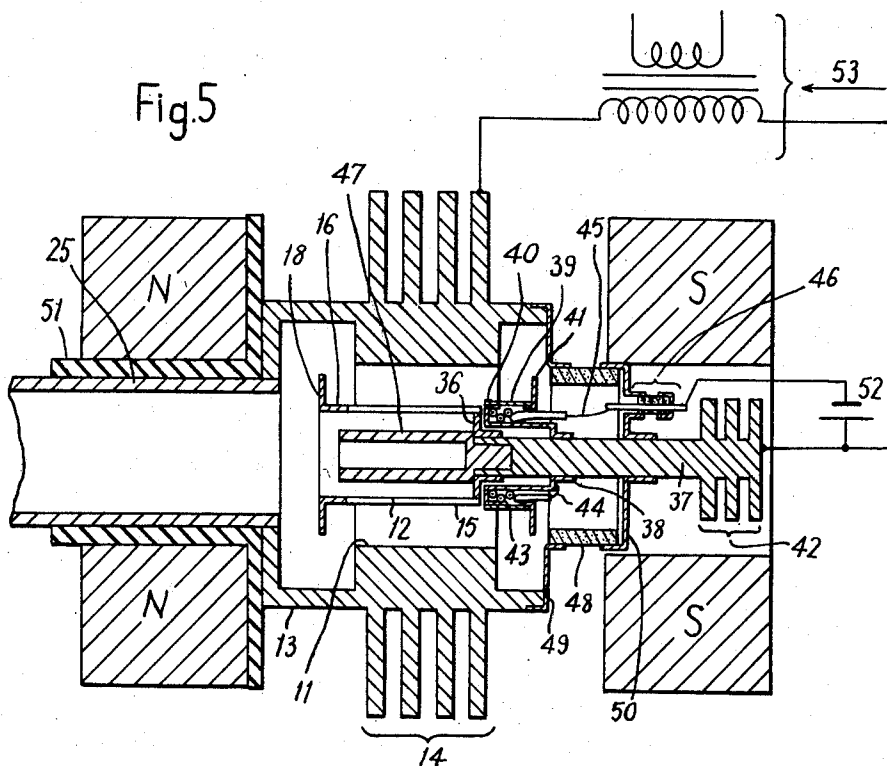
March 12, 1963

E. ROSTAS
ION PUMPS

3,081,020

Filed Feb. 6, 1959

2 Sheets-Sheet 2



Inventor:
Ernest
Rostas.
By
Stone & Mack,
Attorneys.

1

3,081,020
ION PUMPS

Ernest Rostas, Paris, France, assignor to Compagnie Francaise Thomson-Houston, Paris, France, a corporation of France

Filed Feb. 6, 1959, Ser. No. 791,614

Claims priority, application France Feb. 13, 1958
17 Claims. (Cl. 230-69)

In ion pumps (ionization pumps, electronic pumps), the gas to be pumped is ionized in a zone near the high vacuum inlet, an electric field applied to the plasma draws off from it a current of ions and projects it towards an electrode disposed on the side of the primary vacuum. The ions become discharged there and may be aspired by the primary pump. In other models of pumps the ions are absorbed by the electrode itself on which they arrive.

In most known pumps, the ionization of the gas is effected either by a self-maintained discharge between cold electrodes maintained in the gas to be pumped, or by an electronic current originating from a hot cathode. Another means of ionization employs a secondary electron discharge established between cold electrodes to which a high frequency potential is applied. This latter pump combines certain advantages shown by the two types of pumps, namely the type having a self-maintained discharge, and the type having a hot cathode: It is efficient up to the highest vacuums, as is the case for hot cathode pumps, but it has the sturdiness, the simplicity of construction and of maintenance of pumps having a self-maintained discharge.

The present invention has for an object a new pump which comprises a secondary electron discharge, but it differs clearly in the principle of its operation, in particular in the mechanism which produces the secondary electrons. Its most marked characteristic and its specific advantage are that its electric feed does not require high frequency power but is simply effected with D.C. voltage.

The invention is based on the following physical phenomenon: With cylindrical magnetrons, with respect to certain conditions of operation, the strength of the anode current largely exceeds the normal strength of the thermo-electronic emission from the cathode, this being so for example at high anode potentials such as those used in the operation by pulses. Very often a heating-up of the cathode is observed at the same time and it was first believed that this heating-up which may be caused by an electronic bombardment, always was a sufficient explanation of the extraordinary strength of the current. But the phenomenon is shown to be nearly independent of the temperature of the cathode. Not only is it possible to maintain the latter at the initial value by reducing or if necessary by cutting the filament potential, but after the current is established, it is also possible to cool the cathode down to temperatures where normally it no longer emits. Lastly, when replacing the cathode by a cold electrode, currents of the same order of magnitude as with a hot cathode are obtained, provided that a relatively weak initial current is established. For this purpose electrons originating from a hot cathode or produced by a field emission are injected for example in the discharge space. Starting from the initial strength, the current reaches its final stable value after some hundreds of microseconds. It is also possible to trigger off the phenomenon by means of a self-maintained discharge by filling up the tube with a gas at low pressure, for example hydrogen at 10 microns; but the phenomenon itself is not based on an ion discharge, because in pumping the gas, it always subsists up to the highest vacuum. Moreover, it is not necessary for the magnetron to oscillate; a magnetron having a non-divided anode shows a current

2

which is nearly as high as an oscillating multi-cavity magnetron, having the same anode and cathode dimensions.

According to the experimental facts which have just been stated, the discharge phenomenon in question can only be based on a secondary emission effect: A part of the electrons which take part in the discharge must return towards the cathode, endowed with a speed sufficient to liberate secondary electrons there. Moreover, it is found that, for given conditions of operation, the value of the final current depends upon the co-efficient of secondary emission of the cathode material. However hitherto it has not been possible to explain in a satisfactory manner from where originates the kinetic energy of the returning electrons. It is true that in the oscillating magnetron, a portion of the electrons, characterized by certain phases of start from the cathode, are able to absorb high frequency energy instead of supplying it. Therefore the assumption has been put forward that in the operation which appears to be static, oscillations which cannot be detected outwardly are excited owing to a relative movement of the various layers of electrons, a mechanism similar to that occurring in the double beam amplifier. Another assumption is based on an exchange of energy between the electrons when their epicycloid paths intersect.

In spite of the gaps in its theory, the discharge by means of secondary electrons produced in the cold cathode magnetron is an absolutely sure and reproducible phenomenon. It is owing to this phenomenon that it is possible to obtain the high current densities which are necessary to the production of centimeter and millimeter waves of large power. These densities are often multiples of the amount which thermionic cathodes may supply. Cold cathode magnetrons have been constructed in which the discharge is started by means of an auxiliary, hot or cold, cathode or also by means of a self-maintained gaseous discharge.

According to the present invention, the discharge by means of secondary electrons which is produced in crossed electric and magnetic fields and which has just been described is used, as ionization means, in an ion pump. Pumps in accordance with the invention thus comprise a discharge space which is essentially similar to a cylindrical magnetron subjected as the latter to crossed electric and magnetic fields, and means producing an electric field serving to draw off ions, these being aspired, after their discharge, by a primary pump or being absorbed by a body acting as a getter.

The discharge described is in fact a very powerful means of ionization. Already the anode current easily reaches some tens of amperes, but moreover the current arriving on the anode is only a small fraction of the electronic current circulating in the space between anode and cathode and which may ionize the gas contained in this space. The new pump has the advantages listed with respect to the electronic hyper-frequency discharge pump, in particular its sturdiness and its effectiveness with respect to the highest vacuums, but its supply is simpler since it does not require a high frequency power. The discharge structure used may be, in principle, a multi-cavity magnetron oscillating during the operation, but in general it is advantageous to use a smooth anode magnetron which does not oscillate during the discharge, the electronic current reaching approximately the same values in the two types of structures. The anode may be fed either with a D.C. voltage, or by pulses, but also with an A.C. voltage, the tube itself serving as a rectifier. In this latter case, it is advantageous to superimpose an alternating component to the D.C. magnetic field; it is thus possible to ensure, during an appreciable fraction

of the period of alternating voltage, values of anode voltage and of magnetic induction which are approximately optimum for the discharge.

With respect to drawing off ions from the plasma and evacuating them, account must be taken of the fact that the ions produced under the influence of the radial electric field travel in the direction towards the cathode along trajectories which are slightly curved. This renders their elimination by absorption very simple. If the absorbing material envisaged itself has a sufficiently large secondary emission coefficient, as in the case of tantalum, it may be utilised as cathode material. If this is not the case, as with titanium, the cathode may be constituted by a grid which has a great transparency, made of a material having a high secondary emission coefficient, as in the case of tungsten, and which surrounds coaxially the absorbing element: The latter must be brought to a potential which is equal to or more negative than that of the cathode. In the case of ions, the cathode structure has a greater transparency than in the case of electrons, the ion trajectories being nearly perpendicular to the surface of the cathode, whilst the electron trajectories have a steep slope relatively to the perpendicular to this surface. Therefore the cathode elements do not greatly hinder the passing of ions, but are reached by the electrons which may liberate secondary electrons on these elements. This difference of apparent transparency is still stressed further if the cathode elements have a greater extension in the radial direction than in the tangential direction, as for example when they are constituted by flat bars arranged parallel to each other and in such a manner that their narrow sides form the surface of the cathode cylinder.

In pumps provided for operating in combination with a primary pump, the problem of drawing off ions may be solved in the following manner: Inside the cathode, formed as a cage as is described above, an electric field is created communicating to the ions a component of movement parallel to the axis of the cathode. The cathode cylinder is continued at one of its ends or at both its ends by the piping of the primary pump. The ions enter in it and are discharged either on a common electrode or on the walls of the piping itself and are aspirated by the primary pump.

In order to create the necessary electric field inside the cathode, it is possible to use either a negative electrode, possibly in the form of a grid or of a ring and disposed near the inlet of the piping, or a positive electrode near the other end of the cathode or both at the same time. But the invention also comprises a special electrode arrangement, taking into account the fact that the ions penetrating in the cage of the cathode possess, in accordance with their point of origin, radial speeds ranging from zero to a maximum value corresponding to the anode potential. As far as the slow ions are concerned, a weak axial field would suffice to make them enter into the piping of the pump, even in the case of long cathode structures, but in order that rapid ions also are directed towards the opening into the piping, instead of passing radially through the cathode, the field established inside the cathode must in general have a radial component which annuls, at least partially, the component of radial speed of the ions. In principle, any electrode disposed inside the cathode or the piping and brought to a positive potential relative to the latter, creates a field possessing axial and radial components:

In order that the invention may be better understood reference will now be made to the accompanying drawings in which:

FIGURES 1 and 2 are explanatory diagrams,

FIGURE 3 is a longitudinal section through one embodiment of pump according to the invention,

FIGURE 4 is a partial perspective view of part of the structure of the pump of FIGURE 3, and

FIGURES 5 and 6 are longitudinal sections through

two further embodiments of pump according to the invention.

With reference to the creation of the electric field inside the cathode, FIGURE 1 shows a plane electrode 1 disposed in a cylindrical structure 2 but in this case, the field represented by the lines of force 3 decreases rapidly with distance. For that reason, the invention proposes the arrangement of an electrode which, in the form of a body of revolution of decreasing diameter, for example in the form of a cone, penetrates in the cylindrical space enclosed by the cathode. FIGURE 2 shows schematically such an arrangement. The field created by the electrode 4 and shown in the lower part of the figure by the lines of force 5, possesses along the whole of the length of the cathode 6 a shape which is adapted to reflect the ions towards the piping inlet 7. The lines 8 and 9 show schematically the trajectories of two rapid ions. As far as the slow ions are concerned, it may happen that the field makes them come out of the cathode again, as schematically shown by the trajectory 10, but they have acquired in the field an axial speed component, and after passing through the cathode surface once or several times, they also in the end enter into the piping 7.

In many cases the starting of the electronic discharge does not require any special means, it is sufficient to start from an initial pressure of the gas to be pumped, from which becomes established a self-maintained ion discharge; the latter, with the improvement of the vacuum, gives way to the electronic discharge. But in order to be independent from the starting conditions it is advantageous sometimes to dispose in the pump an auxiliary hot cathode or a cold cathode operating by field emission. These auxiliary structures may be disposed for example in an extension of the main cathode.

FIGURE 3 shows a section through a pump intended for operating in combination with a primary pump and in which the electronic discharge is started by an ion discharge produced in the gas to be pumped. The discharge structure is constituted by the cylindrical anode 11 and the cathode 12 in the form of a cylindrical cage. The anode is integral with a metallic enclosure element 13 provided with cooling fins 14. The cathode consists of flat bars 15 having their ends inserted in sleeves 16 and 17 which support the electron reflectors 18 and 19. FIGURE 4 is a partial perspective view in greater detail of the constitution of the elements of the cathode. The cathode structure is supported on one side by the metallic piping 20, directed towards the primary pump, and on the other side through a ceramic washer 21, by the electrode 22. This electrode is intended to create, inside the cathode, the electric field directing the ions towards the piping 20. For this purpose it is connected by three feet, two of which 23 and 24 are visible in the drawing, so that it penetrates, in the form of a cone, in the cage of the cathode. The gas to be pumped flows through the metallic piping 25 to the discharge space. The gas particles, drawn off from the plasma in the form of ions, become discharged on the internal walls of the piping 20 and are aspirated by the primary pump. The casing is completed by the metallic disc 26 welded on the tube 20 and a ceramic tube 27, as well as by connecting elements 28 and 29 protecting the ceramic-metal welds against mechanical stresses. The ceramic tube 27 separates electrically the elements of the tube brought to the anode potential from those brought to the cathode potential. A magnet, the polar ring pieces N and S of which are shown, produces a magnetic field parallel to the axis of the tube. Given a difference of potential between the tubes 25 and 20, an insulating body 30 is interposed between the tube 20 and the polar piece S. It is assumed that, in the arrangement shown, the magnet is at the same electric potential as the primary pump. For that reason a section 32 of the insulating tube, for example made of glass connects the inlet 33 of the pri-

5

mary pump to the outlet 34 of the tube 20. The source 35 connected between the anode and the cathode output 20, supplies the D.C. voltage to the pump.

FIGURE 5 shows a pump in which the ions are eliminated by absorption and which possesses an auxiliary hot cathode intended to start the electronic discharge. The elements constituting the anode body of the pump, the inlet piping and the caged cathode are essentially the same as for the pump of FIGURE 3, and are therefore designated by the same references 11 to 16, 18 and 25; but the caged cathode is supported at one of its ends only, the bars 15 being inserted in the edge of a disc 36 welded on the passage rod 37 of the cathode. The free end of the cathode is provided with a reflecting electrode 18. The rod 37 supports also, by means of the welded sleeve 38, the auxiliary cathode 39. The emitting layer 40, for example of alkaline earth oxides, is situated opposite one of the edges of the anode surface. The other end supports the reflecting electrode 41. The body of this cathode is made of a thin sheet having a low thermal conductivity. The heat transmitted nevertheless to the passage rod 37, and to which must be added the heat produced on the main cathode 12, is dissipated outside the enclosure by means of a radiator 42. The auxiliary cathode is heated by the filament 43, insulated by a layer of alumina and one of the ends of it is connected at 44 to the rod 37. The other end 45 leaves the enclosure by the sealed passage 46. Inside the cathode cage and coaxial with it is disposed the element 47 made of a material absorbing the gas ions, for example made of titanium. The sealed enclosure of the pump is completed by the ceramic tube section 48 and the two plates 49 and 50 whose folded-back edges represent the surfaces for welding respectively to the anode body 12, to the ceramic 48, and to the passage rod 37. The plate 50 contains moreover the sealed filament connection. In the embodiment of FIGURE 5, the magnet, of which the pole pieces N and S are shown, is at the potential of the cathode. For this reason, an insulating body 51 is interposed between the pole piece and the part of the tube brought to the anode potential. The filament of the auxiliary cathode is fed by means of the source 52, whilst the anode potential is supplied in the form of pulses by a pulse generator of which only the output transformer 53 has been shown on the figure. At the beginning of each voltage impulse a normal magnetron discharge becomes established in the space surrounding the auxiliary cathode. Then the cloud of electrons spreads rapidly in the axial direction towards the inside of the structure and generates therein the discharge by secondary electrons.

FIGURE 6 shows a modification of the preceding embodiment of pump. The auxiliary hot cathode is replaced by a field emission structure. The structure of this pump being constituted to a large extent by the same elements as those of FIGURE 5, only the new elements and their functions will be described. The main cathode is provided with a border 54 which ends in a very fine edge facing a tubular electrode 55. The support 59 of this electrode has a plane part 60 situated, relatively to the median plane of the tube, approximately symmetrically to the reflector 18. The base of the support is mounted on the passage element 61 whose two folded-back edges are welded to the ceramic tubes 62 and 63. The connecting elements 64 and 65 complete the hermetic casing of the pump. The electrode 55 is electrically connected to the anode by means of a very high resistance 66.

In the present example, the anode is fed by a source of D.C. voltage 67. As long as the main discharge is not started the strong field prevailing in the vicinity of the edge of the border 54 causes a cold emission there. The greater part of the electrons are directed towards the electrode 55. The current passing through the resistance 66 lowers the potential of 55 to an equilibrium value

6

which is still high but which is lower than the potential of the anode. A certain part of the electrons may thus start towards the anode and these electrons serve to generate a discharge by secondary electrons first around the border 54 but extending rapidly along the whole length of the structure. It is true that a part of the electrons which participate in this discharge leave the rotating cloud, because at one of the ends of the discharge space is situated a positive electrode instead of a reflector. However owing to the high value of the resistance 66, the potential of the electrode 55 very rapidly drops nearly down to zero, for a leakage current which is very much less than that which the mechanism of discharge by secondary electrons would produce. The plane part 60 of the support 59 will then be nearly equivalent to a reflector.

It will be evident to those skilled in the art that the elements constituting the embodiments disclosed above may be combined together as desired. For example the pump of FIGURE 3 may be provided with a radiator in order to cool the cathode, or also may be provided with an auxiliary hot or cold cathode like the pumps shown in FIGURES 5 and 6. Each of the pumps may be fed by a D.C. voltage or by voltage impulses.

It will also be understood that various other modifications may be made without departing from the scope of the invention as defined in the appended claims.

I claim:

1. An ion pump in which a gas to be pumped is ionized and the plasma subjected to an electric field intended to draw off the ions, said pump comprising a discharge structure constituted by two spaced generally cylindrical electrodes coaxially arranged one within the other, a casing, which includes the external electrode, enclosing the space between said two electrodes, the inner of said electrodes having a secondary emission coefficient higher than unity, means for applying a voltage to said inner electrode whereby it is brought to a negative potential relative to the external electrode, magnet means for producing a magnetic field substantially parallel to the axis of the structure and having a strength such that for the potential applied to the electrodes a cascade discharge by secondary electrons may be established between the electrodes, and an inlet extending through said casing for feeding a gas to be pumped to the space between said electrodes.

2. An ion pump as claimed in claim 1 in which the inner electrode having a secondary emission coefficient higher than unity is made of tantalum.

3. An ion pump as claimed in claim 1, in which the inner electrode having a secondary emission coefficient higher than unity consists of a cage member and a further body of generally cylindrical shape is enclosed within said cage member and is able to absorb gases in an ionized state.

4. An ion pump as claimed in claim 3, in which the cage member consists of parallel bars.

5. An ion pump as claimed in claim 1, in which the inner electrode having a secondary emission coefficient higher than unity consists of a cage member, a pipe is connected to one end of the cage member and directed towards a primary pump and means are provided adjacent said cage member for producing an electric field to direct the positive ions towards the inlet of said pipe.

6. An ion pump as claimed in claim 5, wherein the means provided adjacent said cage member comprises a further electrode positioned inside the cage member and adjacent the end opposite that to which the pipe is connected and means for applying a potential to the further electrode so that it is brought to a positive potential relative to the cage electrode and the pipe in order to produce said electric field.

7. An ion pump as claimed in claim 6, in which said further electrode comprises a cone positioned coaxially

7

within the cage member and having its apex facing towards the interior of the cage member.

8. An ion pump as claimed in claim 5, wherein said pipe connected to the cage member has a metallic wall and is shaped so that the ions which enter it are deposited on its metallic wall.

9. An ion pump as claimed in claim 1, including a cathode adjacent said inner electrode and means for heating said cathode.

10. An ion pump as claimed in claim 1, in which at least one member having an edge is disposed at one end of the inner electrode having a secondary emission coefficient higher than unity, and a further electrode is arranged at a small distance from said at least one member and means for applying a potential to said at least one member and said further electrode such that a field emission is produced on the at least one member having an edge.

11. An ion pump comprising an anode having a central generally cylindrical cavity therein, a generally cylindrical cathode arranged in said cavity coaxial with and spaced from said anode, said cathode having a secondary emission coefficient higher than unity, a pipe connected to one end of said cavity for feeding a gas to said pump, a potential source connected to said anode and cathode so that said cathode is at a negative potential relative to said anode and a magnet structure positioned axially at either side of said anode and cathode for producing a magnetic field substantially parallel to the axis of the cathode and having a strength such that at the potential supplied to said anode and cathode the phenomenon of cascade discharge by secondary electrons may be established between the anode and cathode.

12. An ion pump comprising an anode having a central generally cylindrical cavity therein, a generally cylindrical cathode in the form of a cage arranged in said cavity coaxial with and spaced from said anode, said cathode having a secondary emission coefficient higher than unity, a pipe connected to one end of said cavity for feeding a gas to said pump, a potential source connected to said anode and cathode so that said cathode is at a negative potential relative to said anode and a magnet structure positioned axially at either side of said anode and cathode for producing a magnetic field substantially parallel to the axis of the structure and having a strength such that at the potential supplied to said anode and cathode the phenomenon of cascade discharge by secondary electrons may be established between the anode and cathode.

13. An ion pump as claimed in claim 12 comprising a second heated cathode arranged in the cylindrical cavity in said anode adjacent one end of said first cathode.

14. An ion pump as claimed in claim 12 comprising a

8

series of spaced elements disposed at one end of said cathode, and means for applying a potential to said spaced elements whereby they are brought to a potential such that a field emission is produced between them.

15. An ion pump comprising an anode having a central generally cylindrical cavity therein, a generally cylindrical cathode in the form of a cage arranged in said cavity coaxial with and spaced from said anode, said cathode having a secondary emission coefficient higher than unity, a pipe connected to one end of said cavity for feeding a gas to said pump, a potential source connected to said anode and cathode so that said cathode is at a negative potential relative to said anode, a primary pump, a further pipe connected between said cavity and said primary pump, a further electrode positioned within said cathode cage, means for applying a potential to said further electrode so that it is positive to said cathode cage and a magnet structure positioned axially at either side of said anode and cathode for producing a magnetic field substantially parallel to the axis of the structure and having a strength such that at the potential supplied to said anode and cathode the phenomenon of cascade discharge by secondary electrons may be established between the anode and cathode.

16. An ion pump as claimed in claim 15, in which said further electrode is a cone having its apex positioned with said cathode cage and directed towards said further pipe.

17. An ion pump comprising an anode having a central generally cylindrical cavity therein, a generally cylindrical cathode in the form of a cage arranged in said cavity coaxial with and spaced from said anode, said cathode having a secondary emission coefficient higher than unity, a pipe connected to one end of said cavity for feeding a gas to said pump, a potential source connected to said anode and cathode so that said cathode is at a negative potential relative to said anode, a further electrode positioned within said cathode cage capable of absorbing ions, means for applying a potential to said further electrode so that it is at least as negative as said cathode and a magnet structure positioned axially at either side of said anode and cathode for producing a magnetic field substantially parallel to the axis of the structure and having a strength such that at the potential supplied to said anode and cathode the phenomenon of cascade discharge by secondary electrons may be established between the anode and cathode.

References Cited in the file of this patent

UNITED STATES PATENTS

2,755,014 Westendorp et al. _____ July 17, 1956