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[54] **IONIC VACUUM PUMP**

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Related U.S. Application Data

[63] Continuation of Ser. No. 330,960, Dec. 16, 1963, abandoned.

[52] **U.S. Cl.** **417/49**
[51] **Int. Cl.** **F04b 37/00**
[58] **Field of Search** 417/48–51

[56] **References Cited**

UNITED STATES PATENTS

3,535,055 10/1970 Brubaker et al. 417/48
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[57] **ABSTRACT**

A glow discharge pumping device is disclosed having an anode, a sputter cathode, and additional electrode means for controlling the glow discharge. In one embodiment the additional electrode means are two apertured planar electrides positioned between the anode and the cathode. In another embodiment the cathode comprises a rod inside the anode, and the additional electrode means is a grid surrounding the cathode rod in the anode.

5 Claims, 7 Drawing Figures

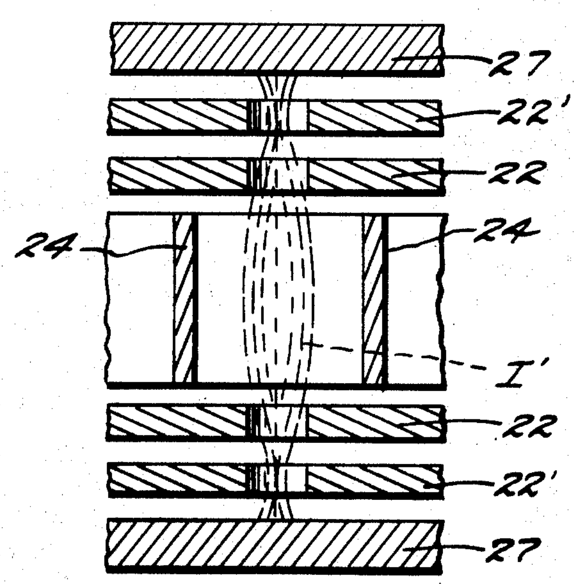


FIG. 1

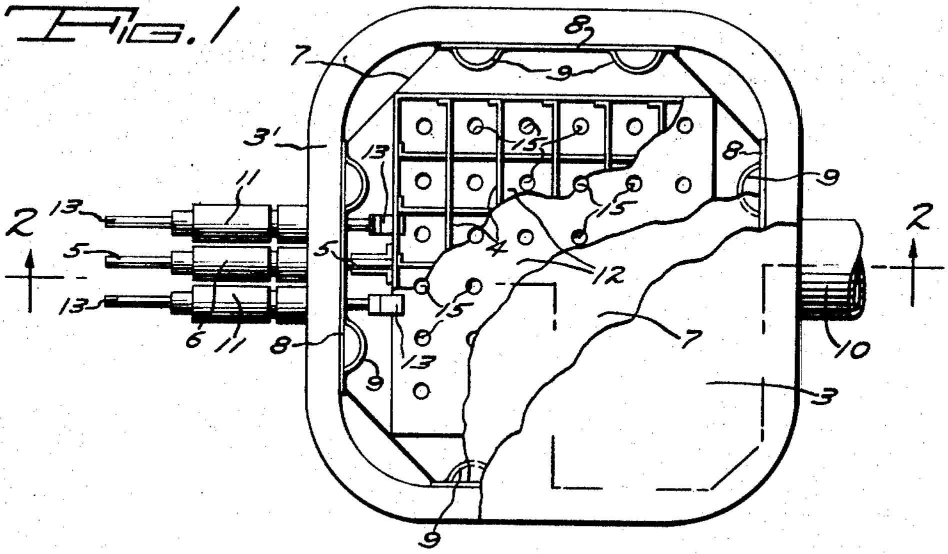
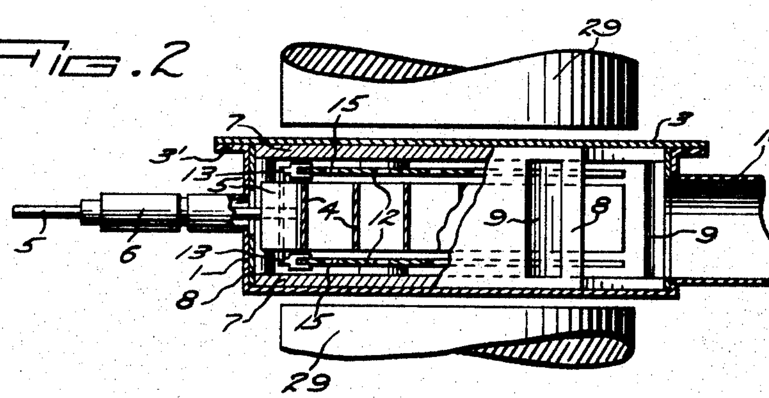


FIG. 2



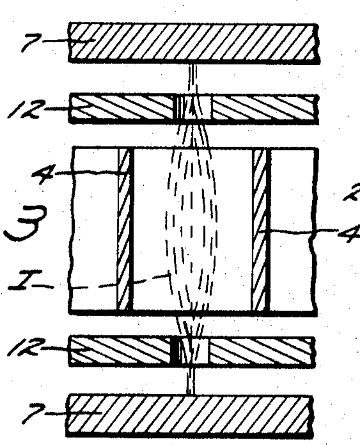


FIG. 3

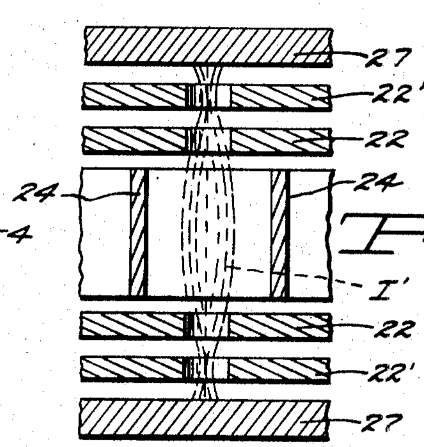


FIG. 4

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FIG. 5

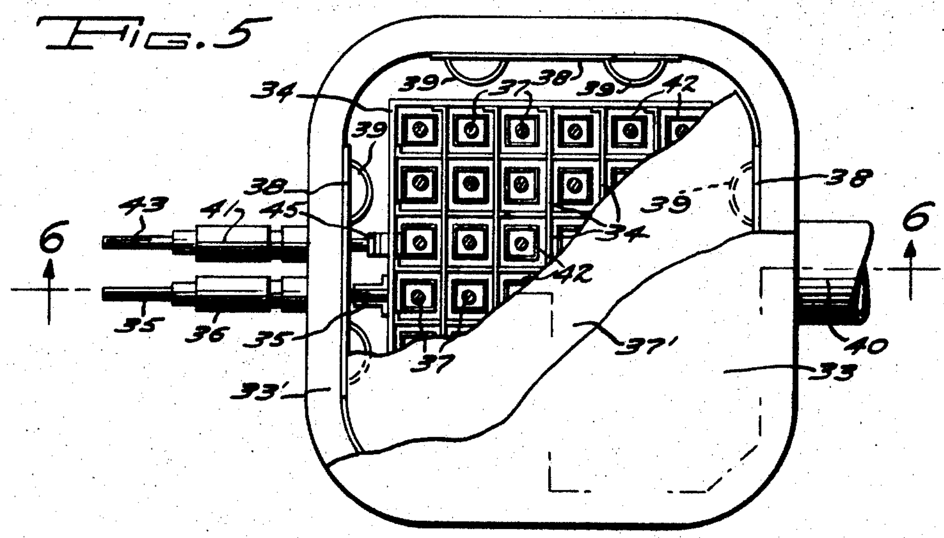
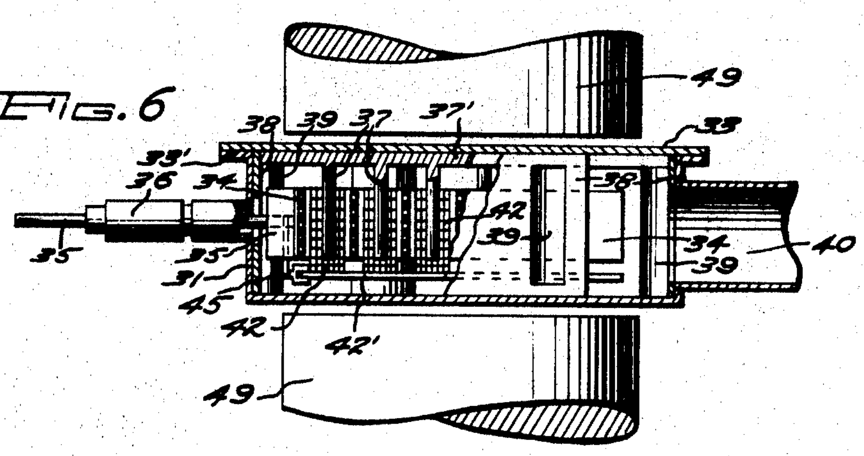


FIG. 6



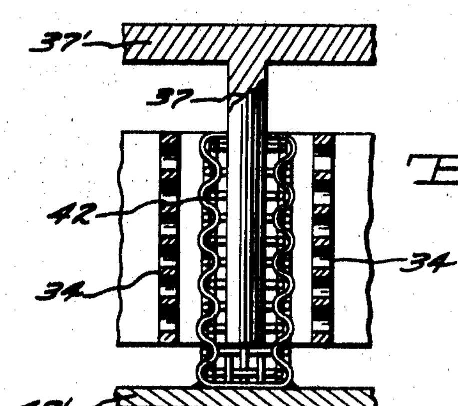


FIG. 7

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IONIC VACUUM PUMP

This application is a continuation of my copending application, Ser. No. 330,960 filed Dec. 16, 1963, now abandoned.

The present invention relates in general to glow discharge devices and more particularly to a method for increasing the pumping of noble gases by increasing the effective ion sputtering of the devices. This increased pumping is obtained by more effective ion sputtering and improves the operating efficiency of devices utilizing the glow discharge principle such as, for example, certain vacuum pumps.

Heretofore, vacuum pumps have been built with an anode having a plurality of glow discharge passageways therein and a cathode structure having for their principle of operation the establishment of a plurality of glow discharges within the interior of the anode and between the cathode plates and having a magnetic field threaded through the anode. Positive ions produced by the glow discharge are directed against the cathode plates in the pump. The impinging ions produce sputtering of a reactive cathode material. The sputtered material is collected upon the interior surfaces of the pump where it serves to entrap molecules in the gaseous state coming in contact therewith. In this manner, the gas pressure within a vessel enclosing the cathode and anode elements is reduced. Vacuum pumps of this type are disclosed and claimed in the U.S. Pat. No. 2,993,638 issued to Lewis D. Hall, et al., for Electrical Vacuum Pump Apparatus and Method.

However, one serious limitation to the above device is found in pumping of noble gases. Such gases, argon, etc., being inert, do not chemically combine readily (getter) with the sputtered material as do the other gases. When an atom of inert gas collides with a free electron, an ion of noble gas is formed in a known manner. This ion of noble gas is buried in the inner surface of the pump. Now if other ions later bombard that same region of the surface, there is a great chance that the ions of noble gas will become re-emitted. When the amount of re-emitted noble gases becomes equal to the amount of buried ions, the optimum pumping level of the vacuum pump is reached.

The principal object of the present invention therefore, is to provide a novel improved sputter ion vacuum pump device wherein the pumping of noble gas is increased.

The main feature of the present invention is the insertion of a third electrode or grid in between the cathode and anode to increase the burial of the noble gases.

Another feature of the present invention is the method whereby re-emission or re-sputtering of buried gases is reduced.

Still another feature of the present invention is the provision of an auxiliary electrode or defocusing grid between the anode and the cathode to defocus the ions so that maximum life of the pump is achieved.

Other features and advantages of the present invention will become apparent upon perusal of the specification taken in connection with the accompanying drawing, wherein:

FIG. 1 is a plan view partly in cross-section of a novel electrical vacuum pump apparatus of the present invention,

FIG. 2 is a cross-sectional view of the structure of FIG. 1 taken along line 2—2 in the direction of the arrows,

FIG. 3 is an enlarged section view of the present invention showing an anode cell, the grid and cathode and the ion column therebetween,

FIG. 4 is another embodiment of the present invention showing a second electrode or defocusing grid with the ion column,

FIG. 5 is a plan view partly cross-section of another embodiment of the present invention,

FIG. 6 is a cross-sectional view of the structure of FIG. 5 taken along line 5—5 in the direction of the arrows, and

FIG. 7 is an enlarged cross-sectional view of a portion of FIG. 6 showing a cathode rod, transparent grid and transparent anode cell.

Referring now to FIGS. 1, 2 and 3 there is shown the novel electrical vacuum pump of the present invention. A shallow, rectangular, flanged, cup-shaped member 1 as of, for example, stainless steel is closed off at its flanged open end by a rectangular closure plate 3 welded about its periphery to the flanged portion 3′ of member 1 thereby forming a substantially rectangular vacuum tight envelope.

A rectangular cellular anode 4 as of, for example, titanium is carried upon the end of a conductive rod 5 as of, for example, stainless steel, which extends outwardly of the rectangular vacuum envelope through an aperture in a short side wall of cup-shaped member 1. The conductive rod 5 is insulated from and carried by the vacuum envelope through the intermediaries of annular insulator frames or cylindrical insulator 6 as of, for example, alumina ceramic. The free end of the conductive rod 5 serves to provide a terminal for applying the positive anode voltage with respect to two substantially rectangular cathode plates 7.

The cathode plates 7 are made of a reactive material and are mechanically locked into position against the large flat side walls of the cup-shaped member 1 via the intermediary of cathode spacer plates 8. The cathode spacer plates 8 as of, for example, stainless steel are provided with semi-cylindrical ears 9 struck therefrom and assuring proper spacing between the cathode plates 7. The cathode plates 7 may be of any one of a number of reactive cathode materials such as, for example, titanium, chromium, zirconium, gadolinium and iron.

Another side wall of the cup-shaped member 1 is apertured to receive a hollow conduit 10 which may be of any convenient inside diameter commensurate with the desired pumping speed. The hollow conduit 10 communicates with the structure (not shown) which it is desired to evacuate.

Interspaced between anode 4 and cathode plates 7 are positioned two rectangular-shaped grid members 12 as of, for example, titanium. The rectangular grids 12 are carried along the end of conductive rods 13 as of, for example, stainless steel which stand outwardly of the rectangular cup-shaped member 1 through apertures in a short side wall thereof. The conductive rods 13 are insulated from and carried by the cup-shaped member 3 through the intermediary of cylindrical insulators 11 as of, for example, alumina ceramic. The free end of rod 13 serves to provide a terminal for applying an intermediate, positive grid voltage with respect to the grounded cathode plates 7 and positive anodes 4.

Grid plates 12 have a number of bored holes 15 therein, the number of holes 15 equalling the number of annular cells of anode 4 to permit gas discharge flow between the cathodes 7 and the anode 4.

As an alternative, grid members 12 may consist of a mesh of titanium wire (not shown), woven together to form rectangles made of titanium wire the same size as the anode cells.

A permanent magnet 29 is positioned with respect to the rectangular vacuum envelope 3 such that the magnetic field of the magnet 29 threads through the individual cellular elements of the anode 4 in substantial parallelism to the longitudinal axis thereof. The strength of the magnetic field is related to the diameter of the individual cellular anode compartments.

In operation of the present invention, the grid 12 between the anode 4 and cathode 7 is of an intermediate positive potential. As a high positive potential is applied to the anode 4 and an intermediate potential is applied to the grid, free electrons trapped in the space between grid 12 and the anode 4 will move to the more positive element, anode 4. However, the magnetic field caused by permanent magnets 29 will cause the electrons to spiral. It is during this spiraling that the electrons collide with atoms of gas in the chamber in and around anode 4 and between anode 4 and grid 12. This collision will produce more free electrons, and further result in positive ions being produced. The ions, being positive, are attracted to the less positive grid 12. Most ions I, as seen in FIG. 3, will pass through the apertures in the grid 12 and strike the grounded cathode 7 with high energy, the ion energy being equal to the difference in potential between anode 4 and cathode 7. The ions will strike cathode 7 with a great velocity and cause a large amount of the reactive cathode material to be sputtered. Some of the sputtered material is then collected upon the interior structure of the pump as, for example, the cathode 7 or the grid 12 where they serve to entrap molecules in the gaseous state coming in contact therewith. A large amount of the sputtered material will pass back up through the grid apertures in a cosine type distribution and collect upon the opposite grids. This sputtered material will serve to entrap gaseous materials thereon but will not be as likely to be re-emitted as gases buried on other pump surfaces.

If, for example, the anode 4 was at a 9,000 volt positive potential and the grid 12 at 8,000 volt positive potential, free electrons in and around anode 4 and the grid 12 will have 1,000 electron volts of energy. The positive ions which pass through the apertures in the grid 12, bombarding the cathode 7 will have 9,000 ion volts of energy. From this it may be seen that electrons having a relatively low (1,000 electron volts) energy will produce ions with a very high (9,000 ion volts) energy. It may be seen therefore that the ions which do not pass through the apertures in grid 12 will be relatively low energy (1,000 ion volts) and will cause little sputtering from that grid electrode.

In the present invention, most of the sputtering will occur at the cathode while most of the burial of gas will take place on the grids and anode. In this way, smaller amounts of buried gas will be re-emitted thereby increasing the overall optimum pumping level of the pump.

In FIG. 4 of the present invention, an auxiliary grid 22′ is shown inserted between cathode 27 and grid 22. The purpose of auxiliary grid 22′ is to defocus the ions I′, as seen in FIG. 4, so that the ions will bombard the cathode over a larger area so that the cathode area available for sputtering and burial of gaseous material will be spread over more of the cathode, thus achieving more effective sputtering and longer cathode life. This defocusing may be effected by either applying a positive potential with respect to cathode 27 to grid 22′ causing the ion columns to become over-focused or to apply a negative potential with respect to cathode 27 and spread out the positive ions.

Referring now to FIGS. 5, 6 and 7, there is shown another embodiment of the present invention. A shallow, rectangular, flanged, cup-shaped member 31 as of, for example, stainless steel, is closed off at its flanged open end by a rectangular closure plate 33 welded about its periphery to the flanged portion 33′ of member 31 thereby forming a substantially rectangular vacuum tight envelope similar to the envelope referred to in FIG. 1.

A transparent, rectangular, cellular anode 34 as of, for example, titanium, is carried upon the end of a conductive rod 35 as of, for example, stainless steel, which extends outwardly of the rectangular vacuum envelope through an aperture in the short sidewall of cup-shaped member 31. The conductive rod 35 is insulated from and carried by the vacuum envelope through the intermediaries of annular insulator frame or cylindrical insulator 36 as of, for example, alumina ceramic. The free end of the conductive rod 35 serves to provide a terminal for applying a positive anode voltage with respect to cathode rods 37 and cathode plate 37′.

Cathode plate 37′ is made of a reactive material and is mechanically locked into position against the rectangular closure plate 33 via the intermediary of cathode spacer plates 38. The cathode spacer plates 38 as of, for example, stainless steel, are provided with semicylindrical ears 39 struck therefrom and insuring proper spacing of cathode plate 37′ from anode 34. As best seen in FIG. 7, cathode rods 37 extend downward from cathode plate 37′ into the rectangular cellular anode 34. Cathode rods 37 may be removeably fitted into cathode plate 37′ by any desired method for easy replacement if deemed desirable.

Another sidewall of the cup-shaped member 31 is apertured to receive a hollow conduit 40 which may be of any convenient inside diameter commensurate with the desired pumping speed. The hollow conduit 40 communicates with the structure (not shown) which is desired to evacuate.

Interspaced between anode cells 34 and cathode rods 37 as best seen in FIG. 7, are positioned rectangular cellular grids 42 as of, for example, titanium, the rectangular cellular grids 42 are carried by means of a stainless steel frame 42′ which is carried along the ends of a conductive rod 43 as of, for example, stainless steel, which stands outwardly of the rectangular cup-shaped member 31 to apertures in a short sidewall thereof. The conductive rod 43 is insulated from and carried by the cup-shaped member 33 through the intermediary of a cylindrical insulator 41 as of, for example, alumina ceramic and is fixedly secured to grid frame 42′ by means of clamp 45. The free end of rod 43 serves to provide a terminal for applying an intermediate positive grid voltage with respect to the grounded cathode rods 37 and plate 37′ and the positive anodes 34. Grid plates 42 are made of strips of interwoven strips of titanium to permit gas discharge glow between cathode rods **37** and the anodes **34**.

A permanent magnet **49** is positioned with respect to the rectangular vacuum envelope **33** such that the magnetic field of the magnet **49** threads through the individual cellular elements of anode **4** substantially parallel to the longitudinal axis thereof. The strength of the magnetic field is related to the diameter of the individual cellular anode compartments.

The operation of the embodiment of FIGS. **5, 6** and **7** is such that the grid **42** is of an intermediary potential between the positive potential of anode **34** and the grounded potential of cathode rods **37**. The main difference in the present embodiment is that a magnetron effect will be the result of the present configuration, that is, electrons will be collected on the outer surface of the grid and of the anode instead of a Penning type discharge as seen in FIGS. **1–4**.

If, for example, the anode **34** was at a 9,000 volt positive potential and the grid **42** at 8,000 volts positive potential free electrons in and around the anode **34** and the grid **42** would have 1,000 electron volts of energy. The positive ions created between anode **34** and grid **42** will pass through the apertures in the grid **42**, and bombard the cathode rod **37** with 9,000 ion volts of energy. These high energy ions will cause much sputtering from the reactive material of cathode rods **37**. Much of the sputtered material will pass back through the grids **42** due to the cosine distribution of the sputtered material and pass through the gridded anodes **34** and be collected on the surfaces of grids of neighboring unit cells.

Now ions which do not pass through the apertures in grid **42** will strike that grid with a relatively low energy (1,000 ion volts) and will be buried therein and cause very little sputtering from the outer surfaces of that grid electrode. Therefore, most of the sputtering will occur at the cathode while most of the ion burial and covering over of sputtered material will take place on the side of the grid away from the cathode rods. In this way very small amounts of gas will be re-emitted thereby increasing the over-all optimum pumping level of the pump.

It may be seen from the foregoing disclosure that two improved vacuum pumps are shown having high energy ions which strike the sputtering cathode to increase the sputtering and low energy ions of noble gases are buried at low velocity on the grid and are covered over by sputtered material from the cathodes thereby increasing pumping of the pump.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A sputter cathode type ionic vacuum pump apparatus including: a vacuum-tight envelope adapted to be connected to a structure it is desired to evacuate; an apertured anode electrode contained within said envelope; a pair of sputter cathode electrodes disposed on opposite sides of said anode electrode, coaxial therewith and contained within said envelope; a first pair of apertured collector electrodes, disposed on opposite sides of said anode electrode, coaxial therewith, each positioned between said anode electrode and a respective one of said sputter cathode electrodes and contained within said envelope; means for supplying operating potentials to said anode and sputter cathode electrodes so as to cause a glow discharge therebetween, said first pair of apertured electrodes being positioned within said glow discharge; means for supplying operating potential to said first pair of apertured electrodes intermediate with respect to said anode electrode and said sputter cathode electrode potentials; means for producing and directing a magnetic field through said anode electrode; and a second pair of apertured electrodes positioned within said envelope on opposite sides of said anode electrode, each of said second pair of apertured electrodes being positioned between one of said first pair of apertured electrodes and the adjacent cathode electrode.

2. The apparatus according to claim **1** wherein, said anode electrode is subdivided into a plurality of lesser hollow open-ended compartments formed by holes extending through said anode electrode defining a plurality of glow discharge passageways therewithin, said first pair of apertured electrodes includes a plurality of apertures aligned with the open-ended compartments of said anode electrode for passage of said glow discharge therethrough, the apertures in said first pair of apertured electrodes being smaller than the holes through said anode electrode to permit interception of a portion of the ions in said confined glow discharge so as to cause sputtering from said first pair of apertured electrodes.

3. The apparatus according to claim **1** including means for applying a positive potential to said second pair of apertured electrodes relative to said cathode electrodes.

4. The apparatus according to claim **1** including means for applying a negative potential to said second pair of apertured electrodes relative to said cathode electrodes.

5. A sputter cathode type ionic vacuum pump apparatus including; a vacuum-tight envelope adapted to be connected to a structure it is desired to evacuate; an anode electrode contained within said envelope divided into a plurality of hollow, open-ended, walled compartments formed by holes extending through said anode electrode, the walls of said compartments being apertured; a sputter cathode electrode contained within said envelope and including a plurality of rod members extending into said open-ended compartments of said anode electrode in a spaced-apart manner; a collector electrode contained within said envelope including a plurality of cellular grids disposed within a respective one of said open-ended compartments of said anode electrode about a respective one of said rod members; means for supplying operating potentials to said anode and sputter cathode electrodes so as to cause a glow discharge therebetween; means for supplying operating potential to said collector electrode intermediate with respect to said anode electrode and said sputter cathode electrode potentials; and means for producing and directing a magnetic field through said anode electrode.

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