Dec. 15, 1964 R. L. JEPSEN ETAL 3,161,802

SPUTTERING CATHODE TYPE GLOW DISCHARGE DEVICE VACUUM PUMP

Filed June 30, 1960

Fig. 1

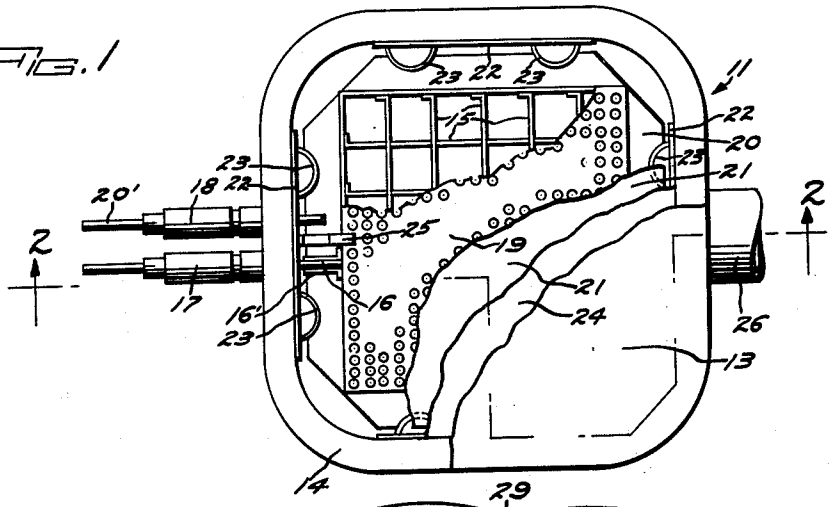


Fig. 2

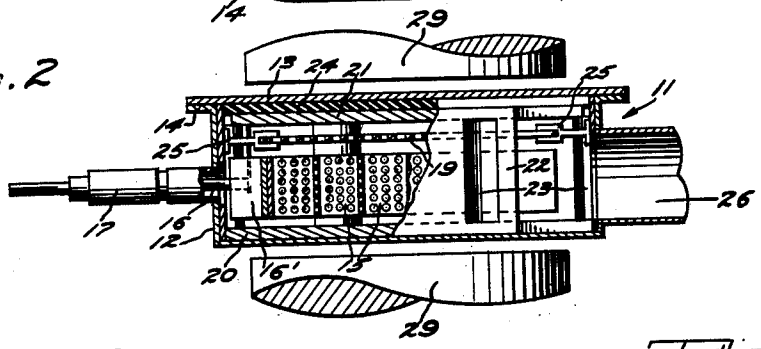


Fig. 3

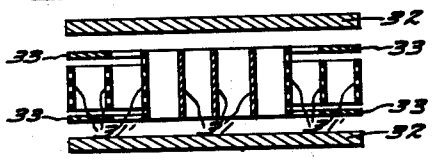


Fig. 5

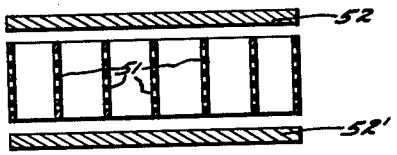


Fig. 4

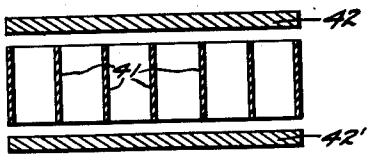
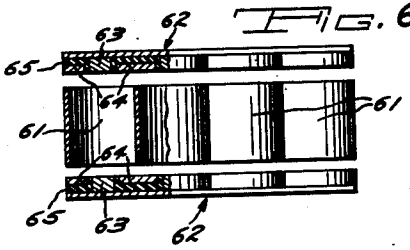


Fig. 6



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SPUTTERING CATHODE TYPE GLOW DISCHARGE DEVICE VACUUM PUMP

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2 Claims. (Cl. 315—111)

The present invention relates in general to glow discharge devices and more particularly to apparatus and method for improving the pumping performance and efficiency in the pumping of noble gases, such as argon.

Heretofore, getter ion vacuum pumps have been built having an anode at a high positive potential positioned between a pair of cathode plates at ground potential and having a magnetic field threaded therethrough, there being established a glow discharge within the interior of the anode and between the cathode plates. Positive ions produced by the glow discharge impinge on the reactive cathode material which is sputtered and collected upon the interior surfaces of the pump where it serves to entrap molecules in a gaseous state coming in contact therewith. In this manner, the gas pressure within the vessel enclosing the cathode and anode elements is reduced. Vacuum pumps of this type are disclosed and claimed in the U.S. Patent 2,993,638 issued to Lewis D. Hall et al. for Electrical Vacuum Pump Apparatus and Method.

It has been observed, however, that when pumping noble gases such as argon, etc., the speed of pumping starts out as high as with other gases but falls off with time at a rate determined at least in part by the pressure of the system. This behavior is due to the fact that the initially high values of pumping speed arise from ion burial in the cathode plates. As the density of noble gas atoms buried in the first few atom layers of cathode metal builds up, such atoms are resputtered or otherwise re-emitted at an increasing rate. Saturation of pumping by this mechanism occurs when the rate of re-emission equals the rate of burial.

It is, therefore, the object of the present invention to provide a novel, improved, gettering vacuum pump device wherein the potentials of certain electrodes are such that useful ion currents are produced but the energies with which these ion currents strike the collector electrodes are too small to produce appreciable sputtering.

The main feature of the present invention is the provision of a glow discharge sputter ion vacuum pump including an apertured anode electrode, a solid sputter cathode electrode disposed on one side of the anode electrode, a solid collector electrode disposed on the opposite side of the anode electrode, and an apertured sputter cathode electrode disposed between the anode and collector cathode electrodes.

Another feature of the present invention is the use of a transparent or gridded anode to provide better access for gas and for sputtered material to the collector electrodes.

Another feature of the present invention is the utilization of auxiliary cathodes which collect low energy ions which are covered over by sputtered material from the sputtering cathodes.

Another feature of the present invention is the provision whereby the sputtering cathode is in the same plane as the collector cathode and is electrically insulated from the collector cathode thus promoting sputtering from the central cathode region to the opposite surrounding cathode areas.

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

FIG. 1 is a plan view partly broken away of a novel electrical 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 a sectional view of the interior of another embodiment of the present invention showing auxiliary cathodes and a transparent anode,

FIG. 4 is a sectional view of another embodiment of the present invention showing anode and cathodes,

FIG. 5 is a sectional view of another embodiment of the present invention showing a transparent anode and cathodes, and

FIG. 6 is an enlarged sectional view of still another embodiment of the present invention partially broken away showng portions of the cathode being electrically insulated from the surrounding cathode.

Referring now to FIGS. 1 and 2 of the present invention, there is shown the novel vacuum pump of one embodiment of the present invention. A shallow, rectangular, flanged cup-shaped member **12** as of, for example, stainless steel, is closed off at its flanged open end by a rectangular closure plate **13** welded about its periphery to the flanged portion **14** of cup-shaped member **12** thereby forming a substantially rectangular vacuum tight envelope **11**.

A rectangular cellular anode **15** as of, for example, titanium is carried upon the end of a conductive rod **16** as of, for example, stainless steel which extends outwardly of the rectangular vacuum envelope **11** through an aperture in a short side wall of cup-shaped member **12**. Cellular anode **15** contains many small apertures in the side walls thereof such as to make the anode **15** appear to be transparent to permit gas flow therebetween. The use of the word "transparent" in the present specification is meant to define an electrode which is gas permeable.

As an alternative, anode **15** may be made of a gridded or mesh design of titanium strips or wire if so desired. A metal clip **16'** is provided to secure rod **16** onto anode **15** by brazing or any other desired means.

The conductive rod **16** is insulated from and carried by the vacuum envelope **11** through the intermediaries of annular insulator frames or cylindrical insulators **17** as of, for example, alumina ceramic. The free end of conductive rod **16** serves to provide a terminal for applying the positive anode voltage with respect to a transparent cathode **19**, sputtering cathode **20** and collector cathode **21**. Another conductive rod **20'** is insulated from and carried by envelope **11** through an insulator **18**. The free end of rod **20'** serves to provide a terminal for applying an intermediate potential to collector cathode **21** relative to the anode **15** and grounded cathodes **19** and **20**.

The three cathodes, **19**, **20** and **21**, are made of reactive material and are mechanically fixed into position in the envelope **11**. Sputtering cathode **20** and collector cathode **21** are fixed into position against the large flat side walls of cup-shaped member **12** via the intermediary of cathode spacer plates **22** as of, for example, stainless steel, provided with semicylindrical ears **23** of insulating material to insure proper spacing of the cathodes **20** and **21** and to electrically insulate the collector cathode **21**. Collector cathode **21** is insulated from the vacuum envelope through the intermediary of an insulator **24**. The cathodes **19**, **20** and **21** may be of any one of a number of reactive cathode materials such as, for example, titanium, chromium, zirconium, gadolinium and iron.

Transparent cathode **19** is mechanically fixed into position between collector cathode **21** and anode **15** by means of support clamps **25** carried from the short side walls of envelope **11**. Transparent cathode **19** has a large number of bored holes therein to freely permit gas discharge flow between collector cathode **21** and anode **15**. As an alterna-

tive, transparent cathode member 19 may consist of a mesh of titanium wire, if so desired.

A permanent magnet 29 is positioned with respect to rectangular vacuum envelope 11 such that the magnetic field of the magnet 29 threads through the individual cellular elements of the anode 15 and substantially parallel to the longitudinal axis thereof.

Another side wall of cup-shaped member 12 is apertured to receive a hollow conduit 26 which may be of any convenient inside diameter commensurate with the desired pumping speed. The hollow conduit 26 communicates with the structure (not shown) which it is desired to evacuate.

The pumps of the present invention employ the known general principles of getter ion pumps utilizing a Penning-type discharge in and about the anode, effected by a high positive voltage applied to the anodes. Free electrons trapped in the space in and around the anodes will move towards the more positive anode element; however, the magnetic field caused by the permanent magnets such as magnet 29 will cause the electrons to spiral. During this spiraling electrons collide with atoms of gases within the chamber in and around the anodes and this collision will produce more free electrons and further result in the forming of positive ions. The ions being positive and less affected by the magnetic field will be attracted to the less positive pump elements.

In the embodiment of the invention shown in FIGS. 1 and 2, sputtering cathode 20 and transparent cathode 19 are at ground potential while collector cathode 21 is at an intermediate positive potential; for example, the anode voltage may be of the order of 3 to 10 kv. and the collector cathode from ¼ to ¾ of the anode potential. Positive ions form in and around anode 15 and will be attracted to the grounded cathodes 19 and 20. Most of the ions which are attracted toward transparent cathode 19 will pass through the apertures in that electrode and strike collector cathode 21 with energy equal to the potential difference between the anode and cathode 21. The intermediate positive potential applied to that electrode will have the effect on the positive ions of slowing them down so that they strike collector cathode 21 with less energy, the effect being that they will be buried in that electrode and therefore cause very little sputtering from collector cathode 21.

Ions which do strike transparent sputtering cathode 19 and sputtering cathode 20 will do so with greater energy and will cause much sputtering from these electrodes as the potential difference between these electrodes and the anode is large. The sputtered material from sputtering cathode 20 will be deflected from cathode 20 in a cosine type distribution and will pass back up through anode cells 15, through the apertures in transparent cathode 19 and cover over the buried ions which strike collector cathode 21. The sputtered material from transparent cathode 19 will also shower down onto collector 21 to aid in ion burial. This covering up or burial of sputtered material will allow a net build up of considerable amounts of buried gases, especially the inert gases which are not gettered because they do not readily combine with other elements as is well known.

In each of the different embodiments of the present invention it will be noted that essentially there are three electrodes having three different potentials—an anode potential of high positive value; a low potential electrode or sputter cathode usually grounded to which ions are attached with great energy and from which sputtering will occur and an intermediate potential electrode or collector cathode which is of such a potential that useful ion currents are products but the energies with which these ions strike the intermediate electrode or collector cathode is too small to produce appreciable sputterings. These electrodes of intermediate potential are exposed to material from the sputter cathode to allow a net build up of material. Referring now to FIG. 3 a cellular anode 31 is inserted between a pair of sputter cathode plates 32. Cellular anode 31 is similar to the cellular anode of FIGS. 1 and 2 with the exception that only the outer anode cell walls 31′ are gas permeable. Further, a pair of annular collector cathodes 33 are interspaced between each sputter cathode plate 32 and the outer transparent portion of anode 31. Anode 31, sputter cathode 32 and collector cathodes 33 are secured within a vacuum tight envelope such as vacuum tight envelope 11 of FIG. 1 in any desired manner and carry electrical potentials of the same order as the corresponding electrodes in FIGS. 1 and 2.

Ionization in and around anode 31 will take place in a known manner and the positive ions will be attracted to sputter cathodes 32 and strike that electrode with high energy causing sputtering of reactive material. The collector cathodes 33 will attract ions with less energy so that little sputtering takes place from that electrode. The collector cathodes 33 are exposed to the sputtered material from sputtering cathode 32 which passes through the transparent portions of anode 31 onto the collector cathode.

One advantage to this embodiment is that the magnetic field provided may be better utilized as a larger anode may be inserted between the sputter cathodes 32 by having the collector electrodes lying in the same plane as the anode.

Referring now to FIG. 4, anode 41 is at a high positive potential while sputtering cathode 42 is at ground potential and collector cathode 42′ is at an intermediate positive potential. Most of the ions formed in and about anode 41 in a known manner will be attracted to grounded sputter cathode 42 with great energy while the ions which are attracted to collector cathode 42′ being at an intermediate positive potential will strike that electrode with a less amount of energy and will cause very little sputtering therefrom, but instead will bury themselves within the reactive material of that electrode. Now, in order to prevent re-emission of the buried ions on electrode 42′, sputtered material from sputtering electrode 42 will cover over the buried ions.

One advantage to the present embodiment is that solid electrodes will give greater life than gridded or transparent type electrodes.

FIG. 5 operates much in the manner as the embodiment shown in FIG. 4 with anode 51 being at the high positive potential, sputter cathode 52 at ground and collector cathode 52′ at an intermediate positive potential and upon which the ions are buried and are covered over with sputtered material from sputtering cathode 52. The one difference in the embodiment of FIG. 5 is that anode 51 is provided with small openings in its side walls to allow more gas access therebetween and also allow sputtered material to pass freely therebetween.

FIG. 6 of the present invention shows still another embodiment of the present invention. A cellular anode 61 consisting of cylindrical cells is interposed between a pair of plates 62. Cathode plates 62 comprise sputtering cathodes 63 centrally aligned with the anode cells and surrounding collector cathode 64 insulated from the sputter cathode segments 63 by insulation 65.

The embodiments set forth in FIG. 6 operate on the same principle as the other embodiments of the present invention. However, the small inset sputter cathodes 63 are at ground potential and attract ions with greater energy than the surrounding cathode 64. It is from these small sputtering cathodes 63, which the high energy ions bombard, that reactive material is sputtered onto the less negative, that is intermediate potential, collector cathode 64 upon which the ion burial and covering over by sputtered material occurs.

It may be seen from the foregoing disclosure that the ions which strike the grounded electrode will do so with high energy effecting much sputtering therefrom while the ions which strike the intermediate potential electrode will do so with relatively low energy and be buried thereon and these buried ions will be covered over from sputtered

material from the grounded sputtering electrode. In this way, the inert gases which are buried in the intermediate potential electrode will be covered over by the sputtered material and thereby greatly diminish the possibility of re-emitting the buried ions to which the noble gases are attached.

While a cellular anode has been utilized to describe the present invention, it is obvious that other workable anode configurations could be used. For example, the anode may comprise a series of parallel plates having a plurality of apertures therein, the apertures being so aligned as to form a plurality of glow discharge passageways confining therewithin glow discharge columns in mutual parallelism extending and directed to the direction of the magnetic field threading the anode and normal to the cathode plates. All of the anode plates may be supported by two common support members which in turn could be supported from the metal clamp 16' described above. These and still other shapes and designs for the pumping element are set forth in copending application, Serial No. 673,816 filed July 24, 1957 by Lewis D. Hall et al., now U.S. Patent No. 2,993,638 dated July 25, 1961.

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 glow discharge sputter ion vacuum pump apparatus including: a vacuum tight envelope adapted to be connected to a structure it is desired to evacuate; an apertured anode electrode defining a glow discharge passageway therethrough contained within said envelope; a solid sputter cathode electrode disposed on one side of said anode electrode and contained within said envelope; a solid collector cathode electrode disposed on the opposite side of said anode electrode and contained within said envelope; an apertured sputter cathode electrode disposed between said anode and said collector cathode electrodes; means for applying operating potentials to said anode, sputter cathode and collector cathode electrodes for initiating and maintaining a glow discharge, said collector cathode electrode being maintained at a potential intermediate with respect to said anode and sputter cathode electrode potentials, whereby ions from said glow discharge striking said collector cathode will cause very little sputtering therefrom; and means for producing and directing a magnetic field through said anode, sputter cathode and collector cathode electrodes so as to enhance said glow discharge.

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, and said apertured sputter cathode electrode includes a plurality of apertures aligned with the open ended compartments of said anode electrode.

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