

Dec. 17, 1968

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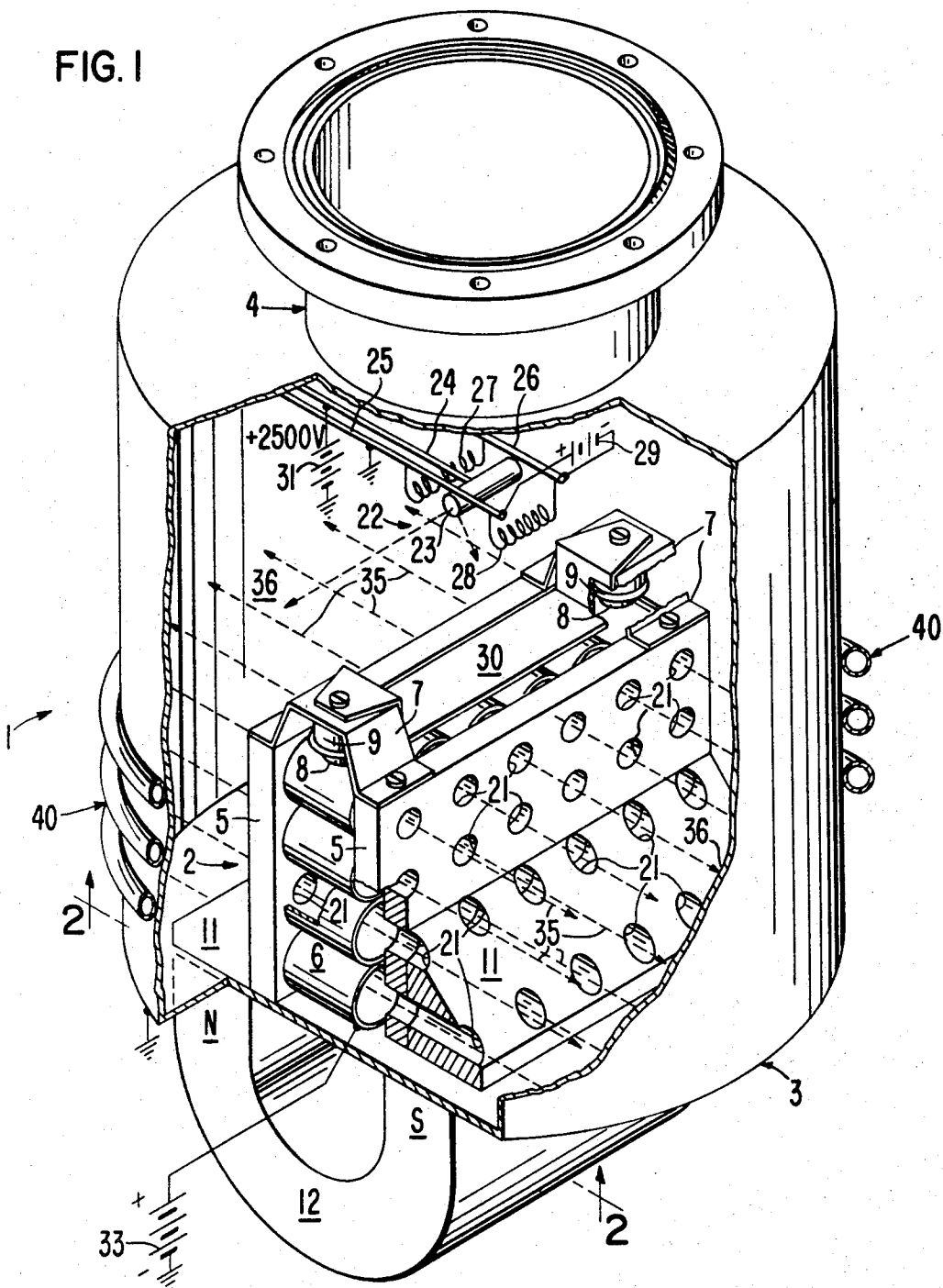
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HIGH VACUUM PUMP EMPLOYING APERTURED PENNING CELLS DRIVING ION BEAMS INTO A TARGET COVERED BY A GETTER SUBLIMATOR

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2 Sheets-Sheet 1

FIG. 1



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FIG. 2

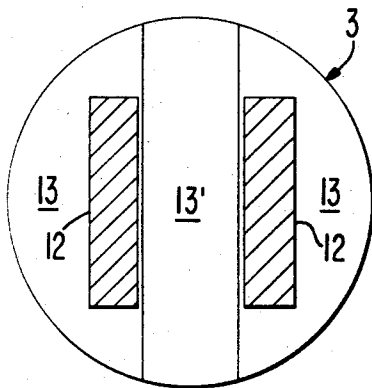


FIG. 3

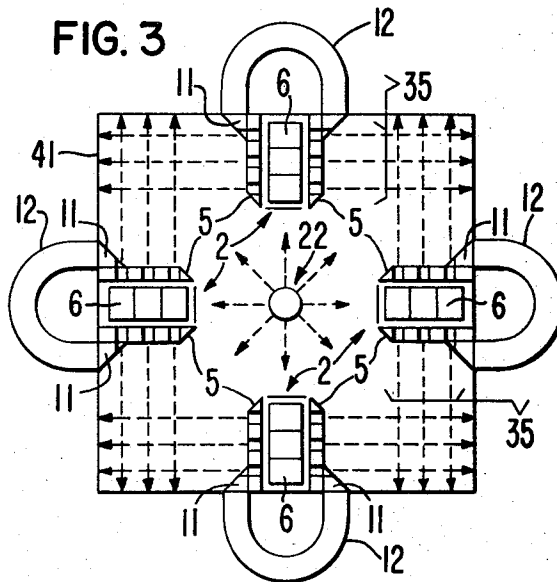


FIG. 4

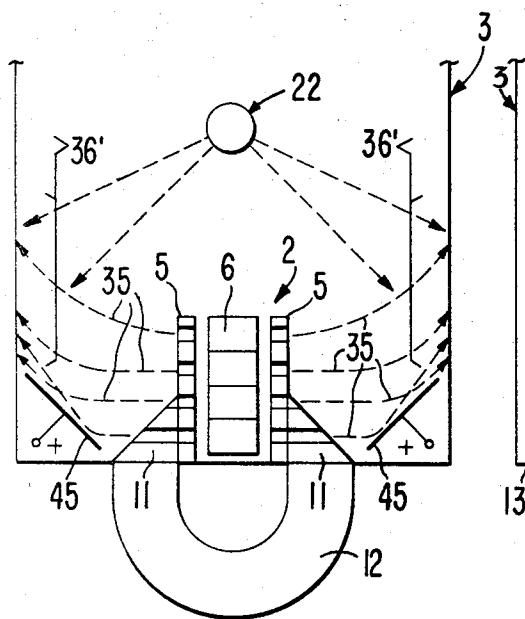
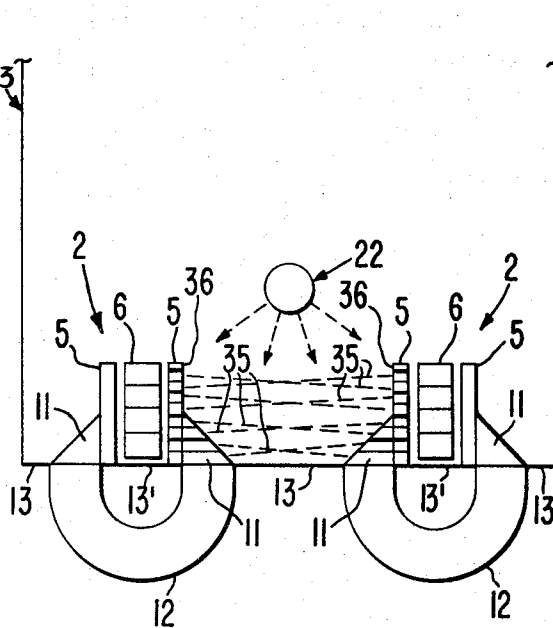


FIG. 5



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ABSTRACT OF THE DISCLOSURE

High vacuum Penning discharge pumps are disclosed wherein the cathodes of the Penning cells are apertured for passage of a beam of ions out of the Penning discharge region. The ion beams are directed into a target electrode at or below the potential of the Penning anodes such that the ions are driven into the target electrode. A getter sublimation element, which may be heated to sublimation temperature by electron bombardment, sublimates getter material, such as titanium, over the ion bombarded surfaces of the target electrode such that the ions are buried in and covered over by the sublimed getter material. Noble gas pumping occurs by means of the gas ionization and ion burial, whereas, the active gases are pumped primarily by means of the sublimed getter material.

One embodiment of the pump of the present invention is disclosed wherein deflector electrodes are provided for deflecting the positive ion beams to target areas of the pump which are more easily covered over by sublimed getter material. In another embodiment, the magnets, for producing the axial magnetic field in the Penning cells, are located outside the vacuum envelope of the pump and a section of the pump's envelope is made of magnetic material to prevent loss of magnetic field. In another embodiment, plural Penning cell pumping elements are disposed around the periphery of the vacuum envelope with such elements projecting toward and surrounding a central sublimator element. In another embodiment, the cathode electrodes of the Penning cells are formed by apertured magnetic pole pieces.

Description of the prior art

Heretofore, sublimation elements have been proposed for use in multiple cell Penning pumps. An example of such a pump is found in U.S. Patent 3,112,864, issued Dec. 3, 1963. In this pump, the sublimator merely sublimed getter material onto exposed surface area within the pump envelope such as the outside surfaces of the anode and the exposed edges of the cathode plates. In such a pump, it was found that the Noble gas pumping speed was not appreciably changed over that speed obtained by the Penning cells taken alone. However, as would be expected, the active gases such as N_2 and O_2 were pumped at the speeds characteristic of a pure sublimation pump.

Summary of the present invention

The principal object of the present invention is the provision of an improved Penning type high vacuum pump.

One feature of the present invention is the provision, in a Penning type multiple cell pump, of an apertured cold-cathode electrode to produce beams of positive ions which are directed into a target electrode wherein they are buried and covered over by getter material sublimed from a sublimator within the pump's envelope.

Another feature of the present invention is the same as the preceding feature wherein the apertured cold-cathode electrode is also a pole piece of the magnet struc-

ture which produces the axial magnetic field in the Penning cells, whereby utilization of the available magnetic field is enhanced.

Another feature of the present invention is the same as any one or more of the preceding features wherein ion beam deflector electrodes are provided for deflecting the ion beams to target areas more easily covered over by sublimed getter material.

Another feature of the present invention is the same as any one or more of the preceding features wherein the magnet for producing the axial magnetic field in the Penning cells is disposed externally of the pump's vacuum envelope and a section of the envelope is made of magnetic material to pass the magnetic flux through the envelope to pole structures inside the envelope, whereby flux leakage is minimized.

Another feature of the present invention is the same as any one or more of the preceding features wherein the Penning cells are grouped in elements which project toward the central region of the pump's vacuum envelope, such central region containing a sublimator unit, whereby a relatively large capacity pump is provided.

Brief description of the drawings

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

FIG. 1 is a perspective view partly broken away and partly schematic, of a high vacuum pump employing features of the present invention,

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

FIG. 3 is a transverse schematic view of an alternative vacuum pump embodiment of the present invention,

FIG. 4 is a fragmentary longitudinal schematic view of a vacuum pump employing features of the present invention, and

FIG. 5 is a schematic diagram of an alternative pump embodiment of the present invention.

Description of the preferred embodiments

Referring now to FIG. 1, there is shown a high vacuum pump 1 of the present invention. The pump 1 includes a set of Penning glow discharge pumping elements 2 disposed at the bottom of a cylindrical vacuum envelope 3 as of non-magnetic stainless steel. The upper end of the cylindrical envelope 3 is connected to a device to be evacuated, not shown, via a flanged throat portion 4.

The Penning pumping elements 2 comprise a pair of cold-cathode plates 5 extending up into the inside of the cylindrical pumping chamber from the bottom wall thereof. The cathode plates are spaced apart by, for example, 1.5". A multicellular anode electrode 6 is disposed between the spaced cathode electrode plate portions 5. The cellular anode 6 comprises an array of closely spaced open-ended tubular metallic members, as of stainless steel, all spot welded together to form the apertured anode structure. In a typical example, the anode cells are 1.2" long and 0.9" in diameter. Alternatively, the cells may be of square cross section.

The cellular anode electrode 6 is supported in insulated relation from the cathode plates 5 by means of a pair of brackets 7 and insulators 8. The brackets 7 span the gap between the cathode plates 5 and the insulators 8 are carried from the brackets 7. The insulators 8 are surrounded by sputter shields 9 to prevent shorting of the insulators 8 by metal condensed on the sides thereof.

The cathode plates 5 also serve as the magnetic pole pieces of a magnetic circuit which produces an axially directed glow discharge confining magnetic field in the

Penning cells of the anode 6. The cathode plates 5 are made of soft iron and are buttressed at the bottom wall of the envelope 3 by a pair of triangular cross section auxiliary pole pieces 11, as of soft iron. A C-shaped permanent magnet 12 is disposed outside the bottom wall of the envelope 3 and the poles of the magnet 12 register through the vacuum wall with the bases of the auxiliary pole pieces 11. The surfaces of the magnetic pole pieces 5 and 11 which abut the envelope are grooved to prevent trapping of gases therebetween.

The bottom wall 13 of the vacuum envelope is as shown in FIG. 2. More particularly, the bottom wall 13 is made of a magnetic stainless steel except for a center strip 13' which is nonmagnetic stainless steel. The poles of the permanent magnet 12 mate with the stainless steel sections 13, whereas the envelope strip portion 13' which lies between the poles of the magnet 12 is nonmagnetic to prevent shunting the magnetic field of the magnet through the envelope. The magnetic sections 13 of the envelope which might be 0.020" thick, permit the magnetic flux of the magnet 12 to readily run through the envelope 3 to the pole structures therein. In a typical example, the magnet 12 produces a field of 1700 gauss through the anode cells.

The pole pieces 5 and 11 are apertured at 21 in alignment with the axes of the cells of the anode 6. In a typical example, the holes 21 are bores 0.5" in diameter.

A getter sublimation pumping unit 22 is disposed above the Penning pumping set of elements 2. The sublimator 22 comprises a slug 23 of getter material such as titanium 0.5" in diameter and 1.0" long which is supported at the end of a tungsten rod 24, as of 0.060" in diameter. Rod 24 is supported at its other end from the envelope 3 by means of a suitable feed-through insulator assembly, not shown. A pair of filament support rods 25 and 26, as of tantalum 0.060" in diameter, are disposed above and parallel to the getter support rod 24. Filament rod 25 is grounded to the envelope 3 and the other filament support rod 26 is supported in a feed-through insulator, not shown, from the envelope 3.

A pair of filamentary thermionic emitters 27 and 28 are connected in parallel across the filament support rods 25 and 26. A filament power supply 29 as of 6 volts, is connected across the filament support rods 25 and 26 for feeding power to the thermionic filamentary emitters 27 and 28, which may be 0.10" diameter tungsten wire. A sublimator power supply 31, for example +2500 v. relative to ground, is connected to the slug support rod 24, thereby making the slug 23 an anode relative to the thermionic emitters 27 and 28 which are disposed along opposite sides of the slug 23.

A conventional glow discharge control unit 33 supplies a positive potential to the apertured anode electrode 6 relative to the grounded cathode electrode structure 5 and vacuum envelope 3 via a suitable feed-through insulator assembly, not shown.

In operation, the pump 1 is bolted to a vacuum tight mating flange on a structure to be evacuated. The composite system is evacuated by mechanical pumps or sorption pumps, not shown, to a pressure on the order of 5×10^{-3} torr. The sublimation pump unit 22 and the Penning pump unit 2 are then energized with their respective operating voltages.

Under these conditions, Penning glow discharge columns are established in each of the cells of the apertured anode 6. The cells serve to define the walls of glow discharge passageways containing the glow discharge columns. In the glow discharge columns, electrons trapped by the crossed electric and magnetic fields spiral back and forth through the cells of the anode 6 between the spaced cathode electrodes 5. In the process, neutral gas molecules are ionized by collision with the electron to produce positive ions. The ions are not appreciably affected by the magnetic field and, thus, are focused by the electric field into an ion beam on the axis of the

cells of the anode 6. The ion beams pass out of the anode cells through the holes 21 in the cold-cathode electrodes 5. Thus, there is produced a multiplicity of parallel ion beams 35, as indicated by the arrow. The ion beams 35 have a beam potential substantially equal to the anode potential and are directed into and bombard those portions of the envelope 3 which are in alignment with the axes of the cells of the anode 6 and bores 21 of the cathode electrode. Thus, a portion of the grounded envelope, at cathode potential, serves as a target electrode structure 36 for bombardment by the positive ions making up the ion beams 35.

In the sublimator unit 22, the getter slug 23 appears as an anode to the filamentary thermionic emitters 27 and 28. Thus, the slug 23 is bombarded by 2.5 kv. electrons to produce heating of the slug 23. The current to the emitters 27 and 28 is adjusted to produce sufficient heating of the slug 23 to cause sublimation of the getter material. A metallic shield 30, operating at ground potential is disposed over the cellular anode between the anode 6 and the filamentary emitters 27 and 28 to prevent electron bombardment of the anode 6.

As used herein "sublimation" is defined to mean that the getter material is caused to be evaporated and condensed on the structure inside the pump envelope. In the process of "sublimation" the getter material may or may not go through the liquid phase. In the particular sublimator shown, it is preferred that the amount of getter material in the liquid phase be minimized. However, in other conceivable arrangements the getter material may be contained in a cup or the like in the liquid phase.

The sublimed getter material is condensed on the target electrode structure 36 where it serves as a layer in which the ions of the beams 35 are buried by being driven into the layer of getter material. In addition, the buried ions are covered over by subsequent layers of condensed getter material derived from the sublimator 22. Water coolant pipes 40 are affixed around the outside of the envelope 3 for cooling the target electrode structure 36. This cooling inhibits outgassing of the target electrode 36.

The ion beam burial process is especially effective for pumping Noble gases. For example, a 42 cell anode 6, in the configuration of FIG. 1, produces a pumping speed of 40 liters/second for pure argon, whereas, the pure argon pumping speed of a comparable sized 42 cell Penning diode using sputter cathode plates is zero liters/second and the argon speed of a 42 cell Penning triode is 8 liters/second. A comparable sized Orb-Ion pump produces a pumping speed of 20 liters/second for pure argon.

Active gases are pumped by the pump of FIG. 1 primarily due to the gettering action of the sublimed getter material which is condensed upon the various interior surfaces of the pump 1. More particularly, the pumping speed of the pump of FIG. 1 is about 1000 liters/second for air. The sublimator 22 taken alone, however, has zero pumping speed for Noble gases such as argon, helium, etc.

Referring now to FIG. 3, there is shown an alternative embodiment of the pump of the present invention. In this embodiment, the pump envelope 41 is made of rectangular shape and the sublimator unit 22 is centrally disposed of the envelope 41 with the Penning pumping sets 2 projecting toward the central sublimator 22 from the side walls of the envelope 41. In this configuration, the pumping speed for the pump can be increased substantially compared to the speed for the configuration of FIG. 1.

Referring now to FIG. 4, there is shown an alternative embodiment of the present invention. In this case, the pump configuration is essentially identical to that of FIG. 1 with the exception that plate-shaped deflector electrodes 45 are disposed adjacent the ion beam paths 35 to deflect the ion beams to a target electrode area

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36' which is positioned closer to the sublimator 22 such that it will receive a faster build-up of getter material. The deflector electrodes 45 are operated at a potential positive with respect to the potential of the anode electrode 6.

Referring now to FIG. 5, there is shown an alternative pump configuration of the present invention. In this embodiment, the pump structure is essentially identical to that of FIG. 1 with the exception that two sets of Penning pumping elements 2 are disposed adjacent each other at the bottom of the envelope 3. In addition, the cathode electrodes 5 are apertured only on the sides which face each other. Thus, the outside surfaces of the cathode electrodes 5 which face each other form the target electrode structure 36 to receive the ion beams 35 and the sublimed getter material.

Although the various pump embodiments have been described with the cold-cathode electrodes 5 also serving as the pole pieces for the magnetic circuit, this is not a requirement. The magnetic pole pieces may be separate and even disposed outside of the pump envelope. For instance, the axial glow discharge confining magnetic field may be provided by an electrical solenoid which is disposed completely outside of the pump envelope.

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 and shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. In a high vacuum pump apparatus, means forming a cold-cathode electrode structure having a pair of spaced electrode portions, means forming an apertured anode electrode structure disposed between said spaced cold-cathode electrode portions, the apertures in said anode structure serving to define a plurality of glow discharge passageways in said anode between said spaced cathode portions, means forming a sublimator for sublimating getter material within the pump apparatus, the improvement comprising, means forming a target electrode structure having a certain portion disposed to receive getter material sublimed from said sublimator, and at least one of said cold-cathode electrode portions being apertured in alignment with the apertures in said anode structure to provide plural ion beam paths emanating from said glow discharge passageways in said anode and passing through the apertures in said cathode electrode structure to said certain portions of said target electrode which are disposed to receive sublimed getter material, whereby the ions of the ion beams are buried in and covered over by the sublimed getter material.

2. The apparatus of claim 1 including, means for producing and directing a magnetic field through said anode structure in a direction passing from one of said spaced cathode portions to the other.

3. The apparatus of claim 2 wherein said spaced cathode electrode portions are made of magnetic material and form pole piece structures of said magnetic field producing means.

4. The apparatus of claim 3 wherein both of said cathode pole piece structures are apertured in alignment with the glow discharge passageways in said anode to provide plural ion beam paths through said pole piece structures.

5. The apparatus of claim 3 including, means forming a vacuum envelope structure enclosing said anode and cathode electrodes, and wherein said magnetic field producing means includes a magnet disposed outside of said vacuum envelope, and said envelope including a section made of magnetic material, said magnetic envelope section being disposed between said pole piece structures on the inside of said envelope with said magnet being disposed on the outside of said envelope, whereby magnetic flux is readily transmitted through said envelope to said pole structures.

6. The apparatus of claim 1 including means forming a deflector electrode structure disposed adjacent said plural ion beam paths for deflecting the ion beams to said portions of said target electrode structure.

7. The apparatus of claim 1 wherein there are plural sets of anode and cathode electrode structures disposed around said sublimator means which is centrally located of said sets of anode and cathode electrode structures.

8. The apparatus of claim 7 including means forming a vacuum envelope structure enclosing said sets of anode and cathode structures, and wherein said sets of anode and cathode structures project from said envelope toward said sublimator means.

9. The apparatus of claim 1 including means for applying an operating potential to said certain ion beam receiving portion of said target electrode structure said applied potential being negative relative to the operating potential applied in use to said anode structure.

10. The apparatus of claim 1 including, means forming a coolant channel disposed in heat exchanging relation with said target electrode structure for cooling said target in use.

References Cited

UNITED STATES PATENTS

3,018,944	1/1962	Zaphiropoulos	230—69
3,212,442	10/1965	Jorgenson et al.	230—69

ROBERT M. WALKER, *Primary Examiner*.