United States Patent [19]

Tom

[11] **3,827,829**

[45] **Aug. 6, 1974**

[54] **SPUTTER-ION PUMP**

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[22] Filed: **Apr. 3, 1972**

[21] Appl. No.: **240,451**

[52] **U.S. Cl.** **417/49**

[51] **Int. Cl.** **F04b 37/02**

[58] **Field of Search** 417/48, 49

[56] **References Cited**

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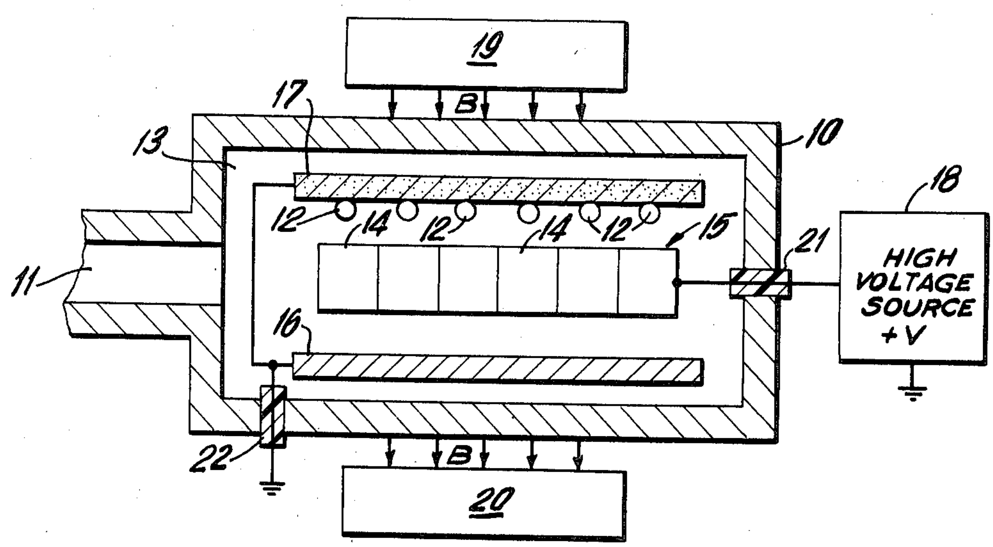
[57] **ABSTRACT**

In a sputter-ion pump employing a high vapor pressure electrode, burn out of the high vapor pressure electrode is eliminated and the inert gas pumping ability of the ion pump is significantly improved by controlling the effective area of the high vapor pressure electrode surface facing the discharge so as to modulate the intensity of the ion beam arriving at the high vapor pressure surface.

6 Claims, 4 Drawing Figures



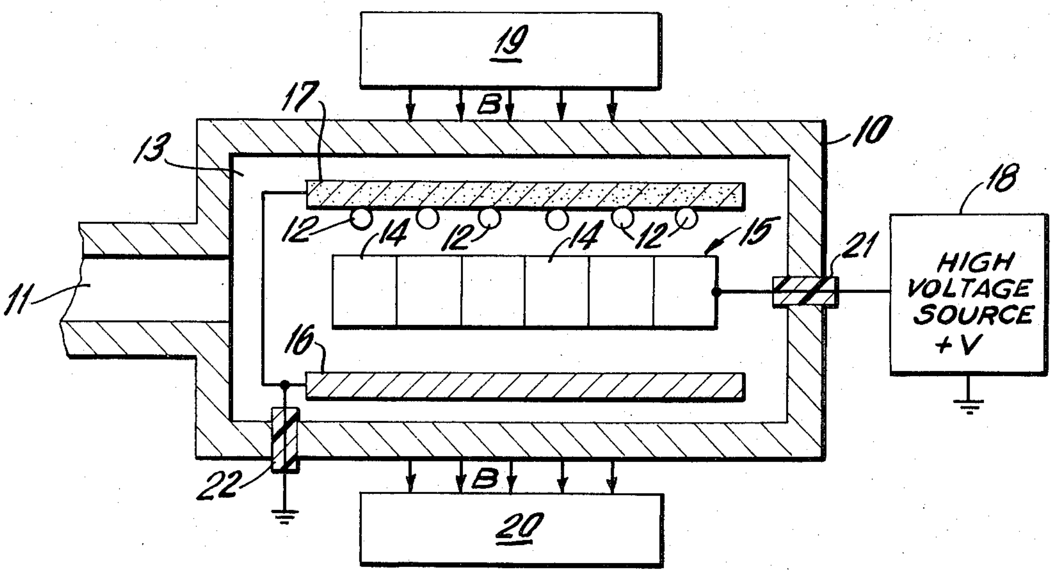


FIG. 1

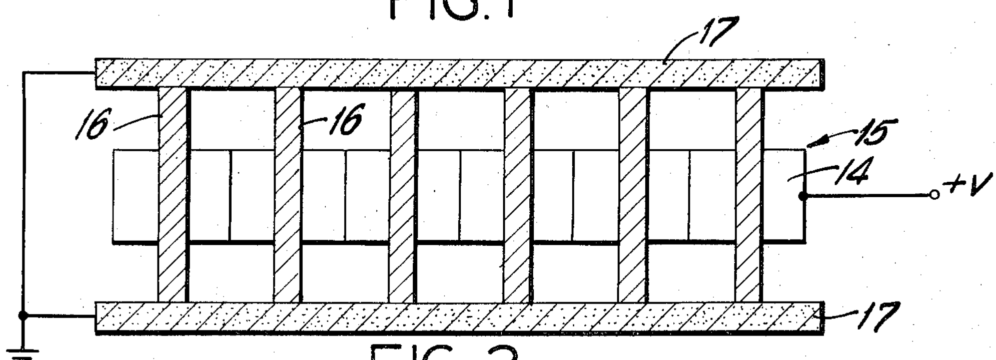


FIG. 2

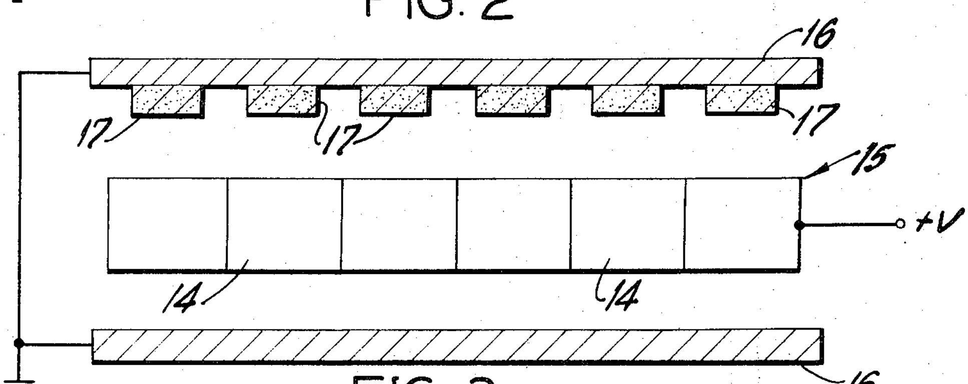


FIG. 3

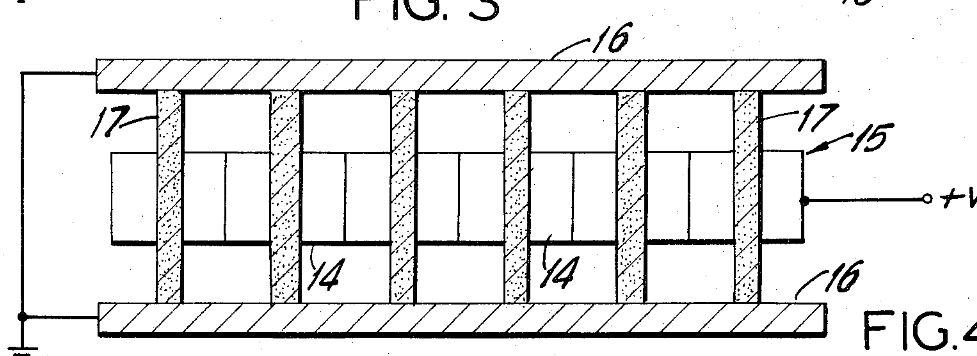


FIG. 4

SPUTTER-ION PUMP

BACKGROUND AND BRIEF SUMMARY OF THE INVENTION

This invention relates to improvements in electronic vacuum pumps of the cold cathode discharge type which operate on the principle of ion sputtering, and more particularly to improvements in sputter-ion pumps employing a high vapor pressure electrode as a source of ions. Such a sputter-ion pump is taught by Lewis D. Hall in the copending, commonly assigned application Ser. No. 231,828, filed on or about Mar. 6, 1972, entitled "Sputter Ion Pumps" and which is incorporated herein by reference.

In sputter-ion pumps, gas molecules are ionized and the ions accelerated under the influence of an electric field to bombard a sputtering electrode of reactive material. The ionized molecules strike the electrode surface causing small amounts of reactive material to become dislodged or sputtered with the resulting sputtered material forming a thin film on a gettering surface whereby the gas molecules are captured to provide the pumping mechanism. Detailed discussions of the phenomena will be found in the extensive literature on the subject. See, for example, U.S. Pat. No. 2,967,257.

Generally speaking, the performance of ion pumps is dependent on the rate of ionization. At high vacua, the number of molecules available for ionization is relatively small, thus limiting pump performance.

In the aforementioned Hall application entitled "Sputter Ion Pumps," it is taught that the pumping performance of sputtering pumps, especially at lower pressures, can be substantially improved by heating a high vapor pressure material such as magnesium with the pump discharge to produce atoms in the vapor phase and then supplying the vapor atoms to the discharge to cause ionization thereof and consequent bombardment of the reactive sputtering cathode to increase sputtering and pumping speed. I have discovered, however, that certain high vapor pressure electrode assemblies in the practice of the Hall invention have a tendency to burn out under certain operating conditions.

In accordance with the present invention, I have found that during pump start-up at pressure ranging from about 10 microns to about 10^{-4} torr the heat generated by the pump discharge can be so intense that too many atoms from the high vapor pressure material are vaporized and that these atoms are ionized and contribute further to the intensity of the ion beam which in turn causes further heating of the high vapor pressure electrode, releasing still a larger number of high vapor pressure atoms for further ionization. This snow-balling effect eventually generates discharge intensities in the order of half a million amps per torr, causing the high vapor pressure electrode to burn out.

In accordance with my present invention the problem of high vapor pressure electrode burn-out is eleminated by controlling the effective area of the high vapor pressure cathode surface facing the pump discharge. In one embodiment this is accomplished by lining the high vapor pressure electrode with relatively low vapor pressure material such a tungsten, molybdenum, tantalum or titanium in a suitable configuration so as to diffuse the ion beam arriving at the cathode surface. With a suitable arrangement of low vapor pressure material to high vapor pressure material, the rate of vaporization of the high vapor pressure atoms is regulated or modulated to the extent that the problem of cathode burn-out is eliminated under actual operating conditions.

Another embodiment of the invention employs rods or strips of gettering material to connect electrodes of high vapor pressure material to thereby control the effective surface area thereof exposed to pump discharge, while a third embodiment involves dispersing rods or strips of the high vapor pressure electrode material on a substrate of gettering material. A final embodiment of the invention involves disposing rods or strips of the high vapor pressure material between sputtering electrodes axially in the direction of the E and B fields in the pump.

The electrode structures of the present invention have been found not only to eliminate the burn-out problem which I perceived, but have also been found to significantly improve the ability of the pump to evacuate inert gases.

BRIEF DESCRIPTION OF DRAWINGS

Having summarized the invention, there follows a detailed description with reference for illustrative purposes to the accompanying drawings forming part of the specification, of which:

FIG. **1** is a partially diagrammatical cross-sectional view of an improved sputter-ion pump in accordance with the present invention; and

FIGS. **2, 3** and **4** are views similar to FIG. **1**, illustrating three alternate ion pump electrode assemblies embodying the present invention.

DETAILED DESCRIPTION

An ion pump embodying the present invention is illustraded in FIG. **1**. The pump is provided with an envelope **10** formed with an inlet **11** to a pump chamber **13** wherein the pumping elements are housed. The pumping elements include a cellular anode **15** formed of a plurality of axially aligned anode cells **14**, and a sputtering electrode **16** disposed to one side of the anode **15**. Electrode **16**, which is constructed of a reactive gettering material such as titanium, is illustratively in the form of a flat plate extending substantially parallel to the major plane of the anode **15**, providing a perpendicular surface to the axial discharges of the individual anode cells **14**.

A high voltage source **18** is connected to the anode **15** through an insulator **21**, while the sputtering electrode **16** is connected to a lower potential, illustratively shown as ground, through an insulator **22**. Two magnetic core pieces **19** and **20** oppositely disposed outside of envelope **10** establish magnetic field B within the chamber **13** extending axially along the anode cells **14** in the direction shown in conventional manner.

Assuming the pressure in chamber **13** has been roughed (reduced) to 10^{-2} torr or below, the conventional aspect of operation of the ion pump is as follows. Upon establishing a sufficiently high potential on the anode **15** relative to the sputtering cathode **16** (e.g., +5 kv), a discharge is produced which results in a flow of electrons from the cathode to the anode. The magnetic field causes the electrons to follow a spiral path and en route they collide with molecules of the gas being evacuated present in the space between the two electrodes, thus converting the molecules into positive ions which are attracted to the negatively charged sputtering electrode **16**. The ionized particles strike the sputtering electrode causing reactive material to sputter from the cathode surface and deposit as a thin film, principally on the anode surface. The gettering action of this thin reactive film provides the principal mechanism by which gas molecules are pumped. As will be appreciated, it is important in the pump operation that this thin reactive film be continuously renewed by sputtering.

It can be seen, however, that at low pressures there are relatively few molecules available for ionization and sputtering. In accordance with the invention of the previously referred to copending Hall application, the ion pump is provided with a separate high yield source of metallic atoms in the gas phase for ionization and sputtering comprising a metal having a relatively high vapor pressure, e.g., magnesium or manganese. The high vapor pressure metal is heated to yield atoms in the vapor phase which are ionized in the discharge for sputtering. Localized heating is conveniently accomplished by the pump discharge.

Referring again to the FIG. **1**, the high vapor pressure metallic source is embodied as a second electrode **17** connected to ground through the insulator **22**, as shown. The high vapor pressure electrode **17** is illustratively in the form of a flat plate disposed in parallel relation to the sputtering electrode **16** on the opposite side of the anode **15**.

It has been found that the separate atomic source provided by the high vapor pressure electrode gives improved performance over the entire pump operating range. Contrary to what might be expected, the presence of the high vapor pressure material in the vacuum chamber does not have a limiting effect on the ultimate pressures attainable.

As described above, I have perceived that there is a distinct tendency for the high vapor pressure electrode material **17** of FIG. **1** to burn out under certain operating conditions. This infirmity may be overcome, in accordance with the present invention, by controlling the effective area of the high vapor pressure electrode which is exposed to pump discharge to thereby eliminate the possibility of burn-out. One embodiment is illustrated in FIG. **1** wherein a series of rods **12** of relatively low vapor pressure material are disposed on the surface of the high vapor pressure electrode material facing the pump discharge. The rods **12** are affixed to the face of electrode **17** by, for example, welds.

FIG. **2** illustrates an alternate electrode assembly of the present invention. The embodiment of FIG. **2** comprises a cellular anode **15** substantially similar to that of FIG. **1**. Disposed on opposite sides of the cellular anode **15** are high vapor pressure electrodes **17** which are illustratively in the form of flat plates extending parallel to the major plane of the anode **15**. A plurality of perpendicular rods or strips of reactive gettering material **16** extend axially through the anode cells **14** to connect the two plates **17**. The high vapor pressure electrodes **17** and the sputtering electrodes **16** are connected to ground in the manner shown. The rods or strips of relatively low vapor pressure gettering material **16** function to control the effective surface area of the high vapor pressure electrodes **17** facing the pump discharge while simultaneously functioning as sources of gettering material. Thus the danger of burn-out of the high vapor pressure electrodes **17** is eliminated.

In the embodiment of FIG. **3**, the electrode assembly includes a cellular anode **15** and a pair of approximately parallel oppositely disposed sputtering electrode plates **16** formed of reactive gettering material. Depending from one of the electrodes **16** towards the anode **15** in axial alignment with the anode cells **14** are a plurality of high vapor pressure electrodes **17** formed of a suitable high vapor pressure material. The problem of burn-out of the high vapor pressure material electrodes is thus solved by dispersing the rods or strips of the high vapor pressure material on a substrate of reactive gettering material.

A fourth embodiment of the present invention is illustrated in the electrode assembly of FIG. **4** which includes a cellular anode **15** and a pair of oppositely disposed sputtering electrode plates **16** formed of reactive gettering material. A plurality of perpendicular rods or strips of high vapor pressure material **17** extend axially through the anode cells **14** substantially parallel to the E and B fields in the pump to connect the two sputtering electrodes **16**. In this manner the danger of high vapor pressure electrode burn-out is overcome.

The invention is more particularly defined in the appended claims.

What is claimed is:

1. A sputter ion vacuum pump comprising means forming a pump chamber, an anode within said chamber, a sputtering electrode of reactive gettering material disposed in operative relation to said anode within said chamber, an electrode of relatively high vapor pressure material disposed in operative relation to said anode and said sputtering electrode within said chamber, means establishing an electrical discharge field between said anode and said electrodes with said anode being at an elevated potential relative to said electrodes, means establishing a magnetic field extending in the direction of said electrical field, said high vapor pressure electrode comprising a plurality of spaced apart high vapor pressure surfaces facing said anode and being adapted to yield vapor atoms for ionization when heated by said pump discharge, and low vapor pressure electrode means forming part of said high vapor pressure electrode comprising a plurality of electrode elements located in spaced apart relation intermediate said high vapor pressure surfaces to thereby control the rate of vaporization of said high vapor pressure electrode and prevent an excessive intensification of said ion discharge.

2. A pump as defined in claim **1** wherein said high vapor pressure electrode material is selected from the group consisting of magnesium, manganese, barium, calcium, aluminum, strontium, cerium and neodymium and combinations thereof and said low vapor pressure material is selected from the group consisting of molybdenum, tantalum, titanium and tungsten and combinations thereof.

3. A pump as defined in claim **2** wherein said sputtering electrode and said high vapor pressure electrode are in the form of flat parallel plates disposed on opposite sides of said anode, said low vapor pressure electrode means comprising a plurality of elements secured in spaced apart relation to the side of said high vapor pressure electrode plate facing said anode.

4. A pump as defined in claim **2** wherein said high vapor pressure electrode comprises a pair of flat parallel plates disposed on opposite sides of said anode and wherein said sputtering electrode and said low vapor pressure electrode means are comprised of a plurality of low vapor pressure material elements extending in spaced apart relation between and connecting said high vapor pressure electrode plates, said elements partially covering the facing surfaces of said high vapor pressure electrode plates.

5. A sputter ion vacuum pump comprising:

A. a pump chamber which may accumulate gases to be evacuated therefrom;

B. an anode situated in the pump chamber;

C. a cathode constructed of a reactive gettering material situated in the pump chamber in operative association with the anode;

D. means establishing an electrical field between the anode and cathode in which the anode is maintained at an elevated potential relative to the cathode;

E. means establishing a magnetic field in the direction of the electric field, said magnetic field encouraging the interaction of electrons with the gases within the pump chamber to form ions thereof, said ions being urged by the electric field to bombard the cathode, thereby causing reactive gettering material to be sputtered therefrom;

F. an electrode constructed of high vapor pressure material which is maintained at a potential relatively lower than the anode and situated in the pump chamber in a position where it will be heated by the ionic discharge of the pump to a point at which vapor atoms of said material will be emitted, said atoms being ionized by interaction with electrons in the pump chamber to increase the ionic bombardment of the cathode; and

G. means situated in the path of the ionic discharge to diffuse said discharge from the high vapor pressure electrode, thereby reducing the intensity of ion discharge to which the high vapor pressure electrode material is exposed, said diffusing means being constructed of a low vapor pressure material.

6. A sputter-ion vacuum pump as described in claim **5** wherein the low vapor pressure diffusion means comprises bars of low pressure material placed on the high pressure electrode in the path of the ion discharge.

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