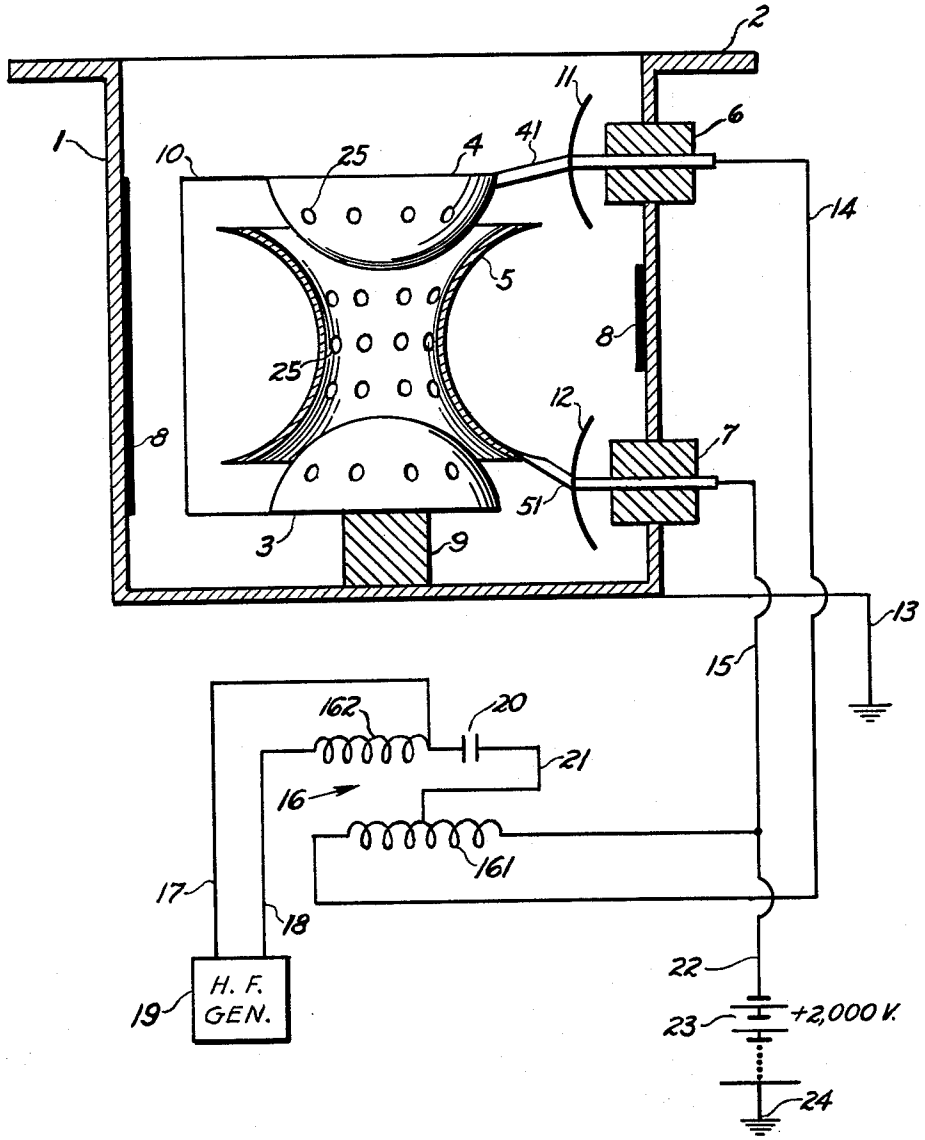
March 8, 1966 HANS-GEORG NÖLLER 3,239,133

PUMP

Filed April 2, 1962



INVENTOR:

Hans-Georg Nöller

BY John E. Toupal

ATTORNEY

United States Patent Office

3,239,133

Patented Mar. 8, 1966

3,239,133

PUMP

Hans-Georg Nöller, Cologne, Germany, assignor, by mesne assignments, to E. Leybold-Holding A.G., Zug, Switzerland

Filed Apr. 2, 1962, Ser. No. 184,481
Claims priority, application Germany, Apr. 1, 1961, L 38,623
10 Claims. (Cl. 230—69)

The present invention relates generally to the pump art for producing high vacuums, and, more particularly, to an ion getter pump.

Ion getter pumps operate with a cold cathode discharge between the anode assembly and the cathode assembly whereby sputtering of the electrode assemblies occurs and the sputtered getter material is deposited on a collecting surface.

Various types of ion getter pumps for generating high vacuums are already known. These pumps are provided with an evaporating or sputtering source with the getter material being either evaporated by heating a supply tank or being sputtered from a metallic surface and through the action of the cold cathode discharge. In these types of getter pumps neutral gas molecules which are present are poorly gettered with respect to ionized particles, and accordingly, additional ionization devices have been used to change the neutral gas molecules into charged or excited particles. In order to provide ionization, there must be an impact with an electron; and, therefore, the ionization process is substantially increased if relatively long electron paths, within the gas volume to be ionized, can be provided, for this will substantially increase the probability of a collision between a neutral gas molecule and an electron.

In the past, in order to provide this desirable increase in the length of electron paths or in their transit time, static magnetic fields have usually been used. Such fields provide the electrons with circular motion components so that the electrons have their paths considerably extended with respect to the originally preferred radial motion in an axially symmetrical system, i.e., a system which is symmetrical with respect to rotation.

There are a great many and considerable drawbacks in using static magnetic fields for the purpose of extending the electron paths. The reason is that in order to obtain a proper effect, a large magnetic field strength is required, and this can be produced only by permanent magnets of great weight, or by magnetic coils which consume a considerable amount of power. Such permanent magnets are thus expensive due to the amount of high grade magnetic material required, and magnetic coils not only consume a great amount of power, but require cooling of the coils which further complicates the device.

The use of a dynamic electromagnetic field to increase the length of electron paths is already known, although not in connection with getter pumps. However, the extension of the electron paths which is accomplished with this known device is not sufficient to maintain the cold cathode discharge in low pressure regions.

With these defects of the prior art in mind, it is a main object of the present invention to provide a getter pump of simple construction which provides proper extension of the electron paths, even in the ultrahigh vacuum region.

Another object of this invention is to provide a device of the character described wherein a dynamic high frequency electromagnetic field and/or a high frequency electric field is employed in order to maintain the cold cathode discharge in low pressure regions.

These objects and others ancillary thereto are accomplished according to preferred embodiments of the invention wherein a getter pump is provided using cold cathode discharge between the anode assembly and the cathode assembly in order to bring about the sputtering of the electrode assemblies. The extension of the electron paths and thus the ionization which is needed to maintain the cold cathode discharge, even in ultrahigh vacuum zones, is provided by simple structural elements and without the use of static magnetic fields. The invention uses exclusively high frequency electric and/or dynamic high frequency electromagnetic fields for maintaining the extension of the electron paths, which is necessary for the electric gas discharge. The electrons produced in the ionization device are thus exposed to the action of high frequency alternating fields and are excited to have pendulum or oscillating movements or motion in substantially closed three-dimensional curves. In this context, it should be understood that the concept of the electric alternating field also is meant to include fields wherein an electrostatic basic component is added to the high frequency alternating field.

Additional objects and advantages of the present invention will become apparent upon consideration of the following description when taken in conjunction with the accompanying drawing in which the figure is a diagrammatic view illustrating the cross section of an ion getter pump constructed in accordance with the present invention.

As one feature of the present invention, a multipole field is provided having any number of pairs of poles and is fed with a high frequency voltage for extending the electron paths. Either a cylindrically symmetrical device or a spherically symmetrical device may be used. However, the spherically symmetrical device is more advantageous if a particularly high efficiency is desired. This type of multipolar field is already known for use in focussing charged particles, for example, devices for separating masses. Considering a multipole field feature, for example, a stabilizing force acts upon the electrons and detains them in the discharge chamber along definite three-dimensional curves. However, this is dependent on a mathematical relationship being maintained between the charge and the mass of the electron, as well as the voltage and its frequency and the geometry of the design used.

This relationship may be expressed as follows:

$$\frac{e \cdot V}{m \cdot \omega \cdot a^2} < 1$$

where

e=the charge,
m=the mass,
V=the voltage,
ω=the frequency,
a^2=the geometrical factor.

This relationship is true for spherically symmetrical devices and for cylindrically symmetrical devices wherein the free space between the two electrodes in hyperboloid form is enclosed by an annular electrode which has a hyperbola as its generatrix.

The factor a of the preceding equation represents the parameter value of the generating hyperbolas which generate the electrode surfaces by rotation about axes of symmetry. The hyperbolas may also be approximated in a manner which is known per se by using rectilinear sections having varying inclinations or by using other curvilinear sections. If the stated conditions are met, then the length of the path becomes theoretically infiinite, i.e., the electrons are permanently stabilized along their paths and may no longer leave the discharge chamber. However, in practical embodiments, no complete stabilization may

be obtained; but the electrons are present within the discharge chamber for a relatively long period of time and thus provide a sufficient increase in the probability of ionization and render it possible to maintain the necessary discharge even with the lowest of pressures, for example, below 10^{-8} mm. Hg. In this respect, the voltage across the electrodes may be so chosen that the ions which are formed are accelerated against at least one of the electrode surfaces and cause sputtering of that surface. Thus, a gettering of the ions by the sputtered electrode material takes place in a getter layer deposited on the electrodes and/or elsewhere.

In another feature of the invention, the electrodes may be perforated so that the ions may pass through them and may, if desired, be accelerated outside of the multipole field by using suitable voltages (e.g. 1000 v.). Also, the electrodes providing the multipole field may be concentrically arranged. The ions impinge upon inner surfaces of the pump body and thus cause sputtering of these surfaces. Under certain circumstances, the inner material which is sputtered from the electrode surfaces by the impinging ions may pass through the electrode perforations and form further active getter layers in the pump casing. Furthermore, these perforations render it possible for the gases in the pump body to enter the discharge chamber which is enclosed by the electrodes.

In still a further feature of the invention, auxiliary ionization agents, which are known per se, may be provided for igniting or initiating the cold cathode discharge for producing a certain minimum number of charge carriers. For example, a system may be used in addition to the cold cathode discharge, such as a Penning-Magnetron, a glow emission cathode, a radioactive arrangement, or a static magnetic field.

Another feature of the invention is the arrangement of the electrode assemblies forming the cold cathode and the anode within a cylindrical coil which is fed with high frequency voltage and by providing additional electrodes with further high frequency voltages and/or direct voltages which stabilize the electrodes, during the discharge, on a path of revolution which preferably does not contact the electrode surface. In this device, the extension of the electron path is accomplished by means of a dynamic electromagnetic field wherein the magnetic fading, according to the Maxwell relationship, brings about rotational electric fields which carry the electrons along extended paths.

The action of the dynamic electromagnetic field for the extension of electron paths is already known, albeit not in connection with the elements of a getter pump. However, the extension of the electron paths which is thus achieved is not sufficient to maintain the cold cathode discharge in low pressure zones, and, therefore, according to the present invention, static or high frequency electric fields must be additionally used. By this means, sufficient stabilization of the electron paths is provided, and with appropriate values of voltage and frequency, a motion component against the electrode surfaces is imparted to the ions at the same time. The ions cause a cathode sputtering at these surfaces. Since the polarity of the electrons is reversed in synchronism with the frequency, when an alternating voltage is applied, a well defined coordination of cathode and anode is no longer possible. Instead, the electrodes temporarily act as cathode parts so that their surfaces are sputtered by incoming ions.

As another feature of the invention, in order to extend the electron path, a high frequency rotational field is applied in connection with additional electrodes to a direct potential or a high frequency potential. The latter is produced between pairs of electrodes to which an out of phase voltage is applied in a manner which is known per se. In the case where two pairs of poles are used, there must be a 90° phase relationship.

As a further feature of the invention, at least one electrode within the electrode system may be provided with a surface coating which causes a multiplication of the impinging electrons by secondary electron emission and are known per se. The electron paths are to be extended in such a manner as to cause a slipping electron bombardment upon the electron surfaces. That is, the electrons, upon bombarding the surface, do so in such a manner that they slide along the electrode surface. In this arrangement, stabilization upon three-dimensional curves which are traversed several times is generally no longer necessary. However, the device may also be arranged so that the electrons, which are fundamentally stabilized upon three-dimensional curves, impinge upon portions of the electrodes provided with an appropriate surface coating, only upon finally leaving the described paths due to the effect of interference. With this arrangement, the newly formed secondary emission electrons are initially likewise stabilized upon the three-dimensional curves.

With more particular reference to the drawing, a cylindrical pump casing **1** is provided having a connection flange **2** which adapts the device for connection to a container (not shown). Two hyperboloid-shaped cathode electrodes **3** and **4** are disposed one above the other within the pump casing **1**. An annular anode electrode **5** substantially encloses the space between the electrodes **3** and **4** and this electrode is shaped having a hyperbola as its generatrix. Electrodes **4** and **5** are supported by electrical conducting support arms **41** and **51**, respectively, which pass through insulating bushings **6** and **7** and are connected to electrical conductors **14** and **15** exteriorly of the pump, with the insulating bushings **6** and **7** providing a vacuum-tight seal between the support arms **41** and **51** and the pump casing **1**.

All of the electrodes are formed of a material having favorable getter properties for cathode sputtering and, in a preferred embodiment, may be sheet titanium. The getter layer **8**, which is formed by material sputtered from the electrodes in the cold cathode discharge, is collected on the inner wall surface of the pump casing **1**.

Electrode **3** is supported on an insulating member **9** which is fastened to the pump casing **1** and is electrically connected with electrode **4** by means of a conductor **10**. Sheet metal shields **11** and **12** are fastened on the supporting arms **41** and **51** in order to prevent a vaporization produced deposit on the inner surfaces of the insulating bushings **6** and **7**. These shields collect the getter material, sputtered from the inner chamber enclosed by the electrodes, on their surfaces and thus protect the insulating surface of the insulating bushings **6** and **7** from having metal deposited thereon.

The pump casing **1** is grounded by means of a conductor **13**. The conductors **14** and **15**, with which the conductive supporting arms **41** and **51** are connected exteriorly of the casing, are connected with a secondary winding **161** of a transformer **16**. The transformer **16** has a primary winding **162** which is connected by means of conductors **17** and **18** with a high frequency generator **19**. A capacitative coupling is providing between the primary winding **162** and the secondary winding **161** by means of a capacitor **20** which is disposed in a connection line **21** between the central tap of the secondary winding **161** and one end of the primary winding **162**. A high voltage battery **23** is provided and has a battery conductor **22** connected with the conductor **15** to thus provide electrodes **3**, **4**, and **5** with a D.C. potential of +2,000 volts which is superimposed with respect to the high frequency generated by generator **19** and which is additional energy with respect to the potential of the pump casing **1**. The other end of the high voltage battery **23** is grounded at **24**.

In the operation of this pump, the electrons are stabilized within the device illustrated, wherein electrodes **3**, **4**, and **5** are provided with perforations **25** and, together with the casing, provide the multiple electrode device. The electrons are stablized on different and closed three-dimensional curves which initiate ionization processes and

thus provide a cold cathode discharge. The ionized gas molecules, which are present in the cold cathode discharge, impinge on definite electrode surfaces, depending upon the phase position of the alternating voltage, and these surfaces are caused to sputter by this impingement. Some of the ions, together with sputtered electrode material, pass through the perforations **25** and are further accelerated by means of the D.C. high voltage which is applied in the space between the electrodes and the wall surface of the pump casing **1**.

The inner wall surface of the pump casing can also be coated with a getter material if desired and used for getter sputtering. In any case the getter layer **8**, which is formed by collected getter material sputtered from the electrodes **3**, **4**, **5** will possess particularly advantageous gas adsorption qualities. The perforations **25** in the electrodes render it possible, on one hand, for the neutral gas molecules to pass from the inner chamber of the pump casing into the discharge chamber enclosed by the electrode surfaces, and, on the other hand, permit passage of the getter material sputtered from the electrode surfaces to the inner wall surface of the pump casing **1**, whereby an effective getter layer is formed.

It will be understood that the above description of the present invention is susceptible to various modifications, changes, and adaptations, and the same are intended to be comprehended within the meaning and range of equivalents of the appended claims.

What is claimed is:

1. In an ion getter pump of the type wherein a cold cathode discharge between separated electrodes provides sputtering of the electrode surfaces, and the sputtered getter material is deposited on a collecting surface, the improvement comprising: high frequency generator means connected to said electrodes and wherein said high frequency generator means and said electrodes are adapted to provide a high frequency electric field which maintains an electric gas discharge between the electrodes by extending the path of produced electrons.

2. A combination as defined in claim **1**, wherein said ion getter pump includes direct current supply means connected to said electrodes and adapted to super-impose a direct current field component on the high frequency alternating field.

3. In an ion getter pump of the type wherein a cold cathode discharge between separated electrodes provides sputtering of the electrode surfaces, and the sputtered getter material is deposited on a collecting surface, the improvement comprising: high frequency generator means adapted to provide a dynamic high frequency electromagnetic field within the pump and between said separated electrodes, and power supply means connected to said electrodes and adapted to provide an electric field between said electrodes wherein said dynamic high frequency electromagnetic field and said electric field between said electrodes will produce a gas discharge within the pump by extending the path of the electrons produced therein.

4. An ion getter pump, comprising, in combination:

(a) pump housing means including a casing and adapted to be connected with a container to be evacuated;

(b) an anode electrode assembly;

(c) a cathode electrode assembly, said anode and cathode assemblies being disposed within said casing and at least some of the surfaces thereof having getter properties;

(d) high frequency generator means connected with said anode and cathode electrode assemblies and adapted for producing a high-frequency alternating field therebetween so as to extend the path of electrons produced within said casing as necessary to maintain an electric gas discharge.

5. An ion getter pump as defined in claim **4**, wherein said electrode assemblies include a pair of electrodes of hyperboloid form.

6. An ion getter pump as defined in claim **5**, wherein the electrodes of hyperboloid form are arranged to be cylindrically symmetrical.

7. An ion getter pump as defined in claim **5**, wherein said high frequency generator means connected to the electrode assemblies is adapted to provide a high frequency alternating voltage of sufficient magnitude so that the ions formed in the electric gas discharge are accelerated against at least one of the surfaces of the electrode assemblies so as to cause sputtering therefrom.

8. An ion getter pump as defined in claim **5**, wherein said electrodes of hyperboloid form are concentrically arranged in the pump casing and define a discharge chamber, said electrode assemblies having perforations therein so that the gases which are present in the pump casing may reach the discharge chamber and the getter material sputtered from the electrode surfaces may be deposited upon inner wall surfaces of the pump casing.

9. An ion getter pump as defined in claim **8**, wherein said electrodes in hyperboloid form are spaced from and oppose one another, and including another electrode at least partially enclosing the free space between said hyperboloid form electrodes by a concentrically arranged rotational surfaces having a hyperbola as a generatrix.

10. An ion getter pump as defined in claim **4**, comprising a surface coating on at least one electrode in one of said electrode assemblies for providing a multiplication of the impinging electrodes by secondary electron emission.

References Cited by the Examiner

UNITED STATES PATENTS

2,993,638	7/1961	Hall et al.	230—69
3,091,717	5/1963	Rutherford et al.	230—69 X

FOREIGN PATENTS

797,232	6/1958	Great Britain.

MARK NEWMAN, *Primary Examiner.*

WARREN E. COLEMAN, LAURENCE V. EFNER, DONLEY J. STOCKING, *Examiners.*