Aug. 12, 1969 L. T. LAMONT, JR 3,460,745

MAGNETICALLY CONFINED ELECTRICAL DISCHARGE GETTER ION VACUUM PUMP HAVING A CATHODE PROJECTION EXTENDING INTO THE ANODE CELL

Filed Aug. 23, 1967 2 Sheets-Sheet 1

FIG. 1

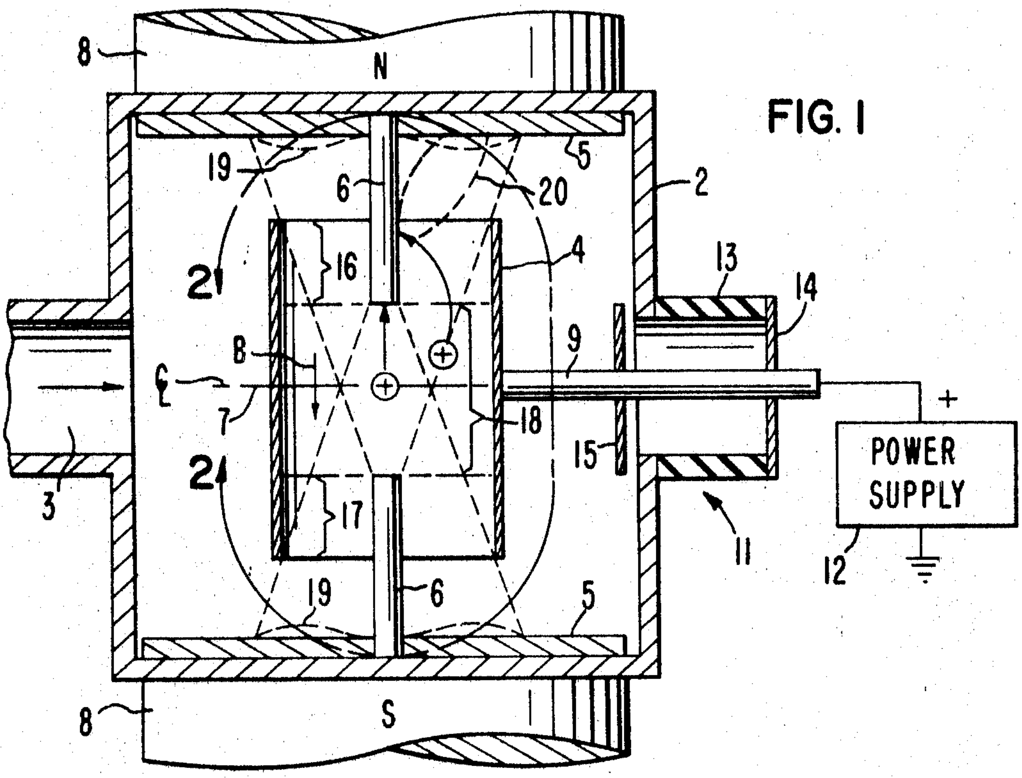


FIG. 2

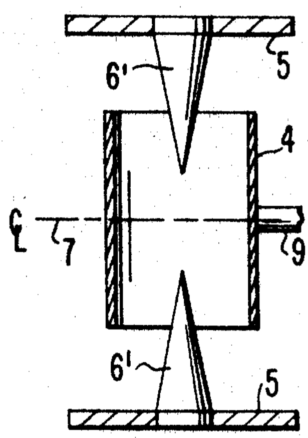
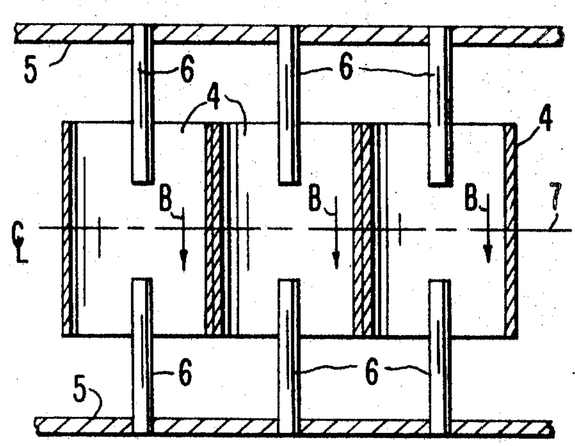


FIG. 3



INVENTOR.
LAWRENCE T. LAMONT JR.
BY
Leon F. Herbert
ATTORNEY

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Filed Aug. 23, 1967 2 Sheets-Sheet 2

FIG. 4

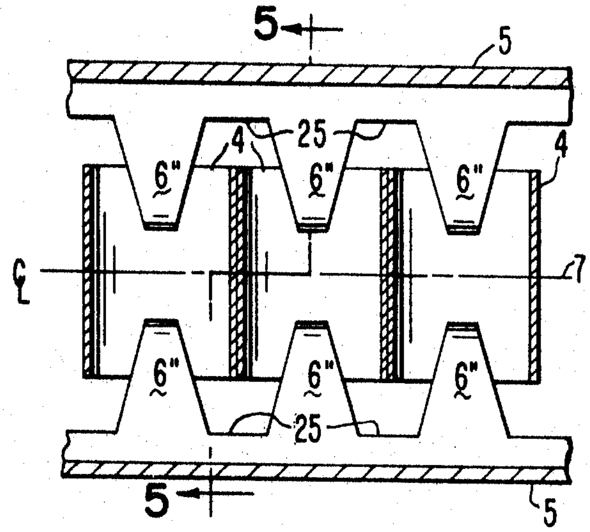
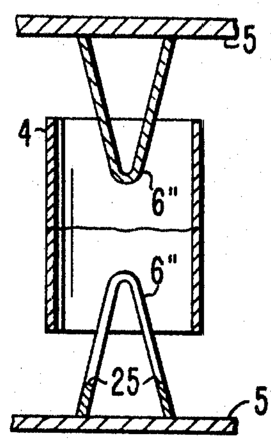


FIG. 5



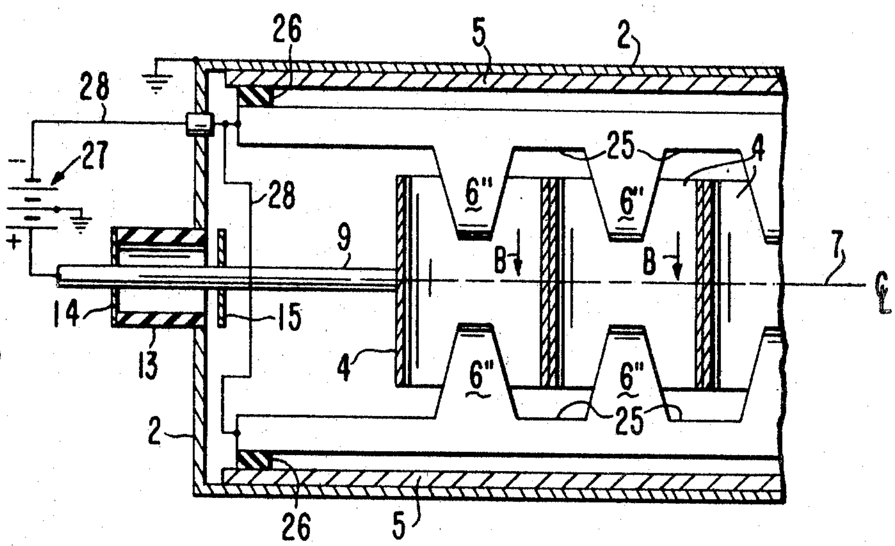


FIG. 6

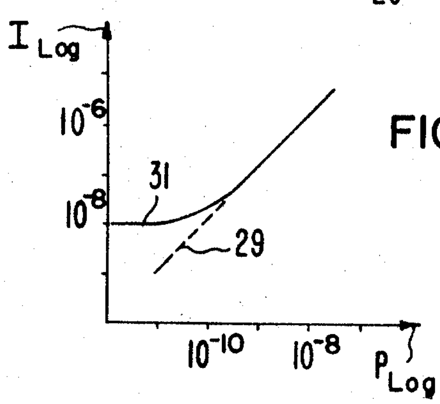


FIG. 7

INVENTOR

LAWRENCE T. LAMONT JR.

BY

Leon F. Herbert

ATTORNEY

United States Patent Office

3,460,745
Patented Aug. 12, 1969

1

3,460,745

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Lawrence T. Lamont, Jr., Palo Alto, Calif., assignor to Varian Associates, Palo Alto, Calif., a corporation of California

Filed Aug. 23, 1967, Ser. No. 662,635
Int. Cl. F04b *37/02;* H01j *7/16*
U.S. Cl. 230—69 10 Claims

ABSTRACT OF THE DISCLOSURE

A magnetically confined electrical discharge getter ion vacuum pump is disclosed. The pump includes an anode structure having a discharge passageway therein. A cathode structure includes an elongated cathode projection, preferably made of tantalum, which extends into the discharge passageway from one end and terminates at a point substantially less than halfway along the length of the discharge passageway to define separate discharge regions therein one being a magnetron discharge and the other being a hollow anode magnetically confined Penning discharge.

DESCRIPTION OF THE PRIOR ART

Heretofore, getter ion pumps have been proposed employing cathode projections extending toward but not into the glow discharge passageways in the anode structure, such projections being coaxially aligned with such glow discharge passageways. One such prior art pump is described and claimed in U.S. Patent 3,112,863, issued Dec. 3, 1963. Such prior cathode projections provided a cathode surface at glancing angles of incidence with the ion trajectories, thereby increasing the rate of sputtering of cathode material onto the remaining portions of the cathode structure. However, in this prior device the increased rate of sputtering was not sufficient to allow a diode type pump to provide stable operation for pumping of noble gases. The pump was made stable for pumping noble gases by insulating the cathode projections from the remaining portions of the cathode structure and operating the cathode projections at a more negative potential than the remaining portion of the cathode. Thus, the ions that were collected on the remaining portion of the cathode, in regions of net buildup of sputtered cathode material, were collected at a potential more positive than that of the cathode projections such that the ions incident in theregion of net buildup of getter material were slowed down to prevent resputtering the collected material with release of the trapped gases.

In another prior art structure, cathode projections were provided in a diode pump. The projections extended coaxially into the anode glow discharge passageways for substantially the entire length of the passageways to define a magnetron type pump. While such a magnetron pump provides improved starting characteristics at low pressures, i.e., pressures less than 10^{-9} torrs, it provides relatively low but stable noble gas pumping speeds since the regions of net buildup of cathode material occur on the end plates and relatively few noble gas ions are driven into the end plates to be covered up by subsequently sputtered cathode material. Such a magnetron type pump is described in U.S. Patent 2,993,638, issued July 25, 1961, and assigned to the same assignee as the present invention.

2

SUMMARY OF THE PRESENT INVENTION

The principal object of the present invention is the provision of an improved magnetically confined electrical discharge getter ion vacuum pump having improved noble gas handling capability.

One feature of the present invention is the provision, in a discharge getter ion pump, of a cathode projection extending into at least one of the discharge passageways of the anode, such cathode projection terminating at a point along the length of the discharge passageway which is less than midway therein to define a combined Penning discharge and magnetron discharge region in the discharge passageway of the anode, whereby the capacity of the pump for pumping noble gases is enhanced.

Another feature of the present invention is the same as the preceding feature wherein the cathode projection is made of a body centered cubic material, whereby the sputtering rate from the cathode projection is increased as compared to hexagonal close packed material such as titanium which has been employed heretofore.

Another feature of the present invention is the same as any one or more of the preceding features wherein the cathode projection is a cylindrical post, whereby sputtering is obtained from the free end of the post as well as from the sides of the post.

Another feature of the present invention is the same as the first or second features wherein the cathode projection is formed by a folded metal member with the folded portion projecting into the anode discharge passageway, whereby fabrication of the cathode projection is facilitated.

Another feature of the present invention is the same as any one or more of the preceding features wherein the cathode projection is insulated from the remaining portion of the cathode and operated at a potential independent of both the anode potential and the other cathode potential, whereby a triode pump configuration is obtained.

Another feature of the present invention is the same as any one or more of the preceding features wherein the pump includes cathode projections extending into the discharge passageway from both ends thereof, whereby the pumping speed of the pump is increased.

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

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a sectional view of a discharge getter ion pump incorporating features of the present invention,

FIG. 2 is a reduced sectional view of an alternative embodiment of a portion of the structure of FIG. 1 delineated by line **2—2**,

FIG. 3 is a fragmentary sectional view of an alternative embodiment of the present invention,

FIG. 4 is a fragmentary sectional view of an alternative embodiment of the present invention,

FIG. 5 is a sectional view of a portion of the structure of FIG. 4 taken along line **5—5** in the direction of the arrows,

FIG. 6 is a fragmentary sectional view of an alternative embodiment of the present invention, and

FIG. 7 is a plot of ion current I vs. pressure P depicting the ion current characteristics of the pump of the present invention as compared with the prior art pumps.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1 there is shown a magnetically confined electrical discharge getter ion pump incorporating features of the present invention. The pump includes a hollow vacuum envelope **2** having an inlet port **3** in gas communication with a device to be evacuated, not shown. A hollow cylindrical anode structure **4** is disposed within the envelope **2** between a pair of cathode plates **5** which are made of a suitable getter material such as for example titanium. A pair of cathode projections **6**, such as cylindrical posts, are coaxially aligned with the axis of the cylindrical anode **4** and extend from the cathode plates **5** to well within the anode cylinder **4**. The posts **6** terminate at a point within the cylindrical anode **4** which is substantially less than midway along the length of the cylindrical discharge passage in the cylindrical anode **4**. The midpoint of the cylindrical anode **4** is defined by the line identified by **7**. The vacuum envelope **2** is disposed between the poles of a permanent magnet **8** for producing a discharge confining magnetic field B which is directed axially through the electrical discharge passageway **4** in the anode structure.

The cathode posts **6** and cathode plates **5** are electrically connected to the envelope **2** which is operated at ground potential. The anode structure **4** is supported on a conductive rod **9** which extends out of the vacuum envelope **2** through a feed-through insulator assembly **11**. The rod **9** is connected to a power supply **12** for operating the anode **4** at a suitable positive potential with respect to ground such as +6 kv. The feed-through insulator assembly **11** includes a cylindrical insulator member **13** as of alumina ceramic sealed at one end to the envelope **2** and at the other end to a metallic diaphragm **14** which is sealed to the post **9**. An annular sputter shield **15** is carried upon the rod **9** to shield the insulator **13** from sputtered cathode material.

In operation, the pump is first evacuated by means of a suitable mechanical or sorption pump, not shown, to a pressure on the order of 10^{-3} torrs. The anode potential is then applied to initiate a magnetically confined electrical discharge in the gas within the hollow interior of the cylindrical anode structure **4**. The inside wall of the cylindrical anode structure defines a discharge passageway axially aligned with the magnetic field B. The axial extent of the posts **6**, which is coextensive with the end portions of the discharge passageway, defines magnetron interaction regions **16** and **17** at the ends of the discharge passageway. In the region between the free ends of the posts **6**, there is defined a magnetically confined Penning discharge region **18**.

A certain fraction of the positive ions generated within the Penning discharge region **18** bombard the posts **6**. Certain of these ions are generated on the axis of the discharge passageway and bombard the free end portions of the posts **6**. Upon bombardment of the ends of the posts by the positive ions, getter material is sputtered from the ends of the posts along straight lines radiating away from the ends of the posts. A substantial percentage of the sputtered material is collected in an annular ring on the opposed cathode plate **5** as indicated by dotted lines **19**. This sputtered material results in a net buildup of collected getter material into which noble gas ions may be buried and covered over by subsequently collected getter material on the cathode plates **5**.

Certain other ions generated off the axis of the Penning discharge region **18** bombard the sides of the posts **6** resulting in additional sputtering of cathode material from the posts onto the cathode plates **5**. A preponderance of these ions bombard the posts **6** at glancing angles of incidence, thereby resulting in increased sputtering from the posts as compared to ions whch strike the posts at angles normal to the surface of the posts. These ions which bombard the posts with glancing angles of incidence cause a preponderance of the sputtered material to be sputtered along rays leaving the cathode surface at substantially the same angle as the angle of incidence of the impinging ions. As a result, the glancing angle of incidence ions produce lobes of sputtered material, indicated at **20**, which further add to the net buildup of cathode material in the annular ring pattern indicated at **19**. Other ions which do not intercept posts **6**, bombard the cathode plates **5** principally in the region of most intense net buildup of sputtered cathode material where they are either gettered or buried by subsequently sputtered cathode material.

It is found that the pump configuration of FIG. 1 is especially useful for pumping noble gases due to the relatively large net buildup of sputtered cathode material on the cathode plates **5**.

In a preferred embodiment, the cathode posts **6** are made of a body centered cubic material such as zirconium, molybdenum or tantalum to increase the rate at which the cathode material is sputtered from the posts as compared to prior cathode materials such as titanium which is hexagonal close packed material and, therefore, relatively difficult to sputter at glancing angles compared to body centered cubic material. Tantalum is found to be especially useful for pumping gases such as air which contain a substantial amount of hydrogen, which comes from dissociation of water vapor, since solubility of hydrogen in tantalum is on the order of 20,000 times greater than the solubility of hydrogen in molybdenum.

Prior art serrated cathode plates, as employed in diode type pumps, have provided a pumping speed for argon which is approximatley 6% of the pumping speed of nitrogen. In a pump of the configuration as shown in FIG. 1 and employing tantalum posts **6**, the pumping speed for argon was approximately 26% of the pumping speed for nitrogen, thus representing approximately a four times increase in the pumping speed for noble gasses as compared to prior art diode pumps using serrated cathode plates. The pump of FIG. 1 pumps active gases at about the same rate as prior art diode pumps.

The cathode posts **6** preferably have a diameter less than 20% of the diameter of the discharge passageway to prevent producing too great a disturbance in the electric field geometry of the discharge cell and intercepting deposition of sputtered cathode material onto the cathode plates **5**. On the other hand, the cathode posts **6** should not be too small in diameter, or else substantially no sputtering will be obtained from the posts **6**. More specifically, the posts **6** preferably have a diameter greater than 0.030 inch.

Referring now to FIG. 2 there is shown an alternative embodiment of the present invention. In this embodiment, the structure is substantially the same as that described with regard to FIG. 1 with the exception that cathode posts **6'** which project into the discharge passageway in the anode **4** are of a conical shape as opposed to the cylindrical shape of the posts **6** of FIG. 1. The mode of operation is substantially the same as that previously described with regard to FIG. 1 with the exception that the axial alignment of the conical posts **6'** is more critical than that of the cylindrical posts **6** since slight misalignment of the conical posts **6'** with respect to the axis of the discharge passageway results in substantially reduced sputtering from the ends of the conical posts **6'**.

Referring now to FIG. 3, there is shown an alternative embodiment of the present invention. In this embodiment, the structure is substantially identical to that previously described with regard to FIG. 1 except that the anode structure **4** includes a plurality of discharge passageways coaxially aligned with the discharge confining magnetic field B. The multiple discharge passageway anode and pumps using same have increased pumping capacity, the pumping capacity being increased with an increase in the number of anode cells.

Referring now to FIGS. 4 and 5, there is shown an alternative embodiment of the present invention. In this embodiment, the structure is substantially the same as that previously described with regard to FIG. 3 with the exception that the cathode projections which extend into the discharge passageways of the anode structure **4** are formed by a folded piece of sheet metal which is serrated at **25** to form the cathode projections **6″**. The folded metal structure is made of a suitable getter material, as previously described for the posts **6**. The folded metal structure may be affixed to the cathode plates **5** or suspended above the cathode plates **5** by a suitable support structure, not shown. The folded metal cathode projections **6″** function in essentially the same manner as the cathode posts **6** and **6′** previously described with regard to FIGS. 1 and 2.

Referring now to FIG. 6, there is shown an alternative embodiment of the present invention similar to that shown in FIG. 4 except modified such that the cathode structure **6″** which projects into the anode discharge passageways **4** may be operated at a potential more negative than the cathode plates **5** to obtain a triode pump configuration. More specifically, the apparatus is substantially identical to that of FIG. 4, except that the folded metal cathode projections **6″** are supported from the cathode plates **5** via insulative members **26** to permit the cathode projections **6″** to be operated at a cathode potential independent of the cathode plates **5**. In particular, a power supply **27** is connected to the cathode structures **6″** via leads **28** for operating the cathode projections **6″** at a potential more negative than the cathode plates **5** by, for example, 2000 v. By operating the cathode projections **6″** at a potential substantially more negative than the cathode plates **5**, sputtering from the cathode projections **6″** is increased in accordance with the voltage applied between these projections **6″** and the anode cells **4**, whereas the ions which bombard the cathode plates **5** bombard the regions of net buildup of cathode material with velocities less than the velocities at which they bombard the cathode projections **6″**. As a result, there is obtained a relative reduction in the resputtering of the cathode material which has been built up on the cathode plates **5**. Thus, typical triode operation is obtained. However, performance of the triode pump is improved over prior triode pumps due to the provision of the combined magnetron and Penning discharge regions in the anode cells and due to the increased rate of sputtering of cathode material from the cathode projections **6″**.

Referring now to FIG. 7, there is shown a plot of ion current I vs. pressure P depicting the characteristics of ion getter pumps of the present invention as contrasted with those of the prior art. More specifically, the dotted line **29** depicts the typical ion characteristic of the prior art diode pump employing magnetically confined Penning discharge cells. In this instance, the ion current I decreases with decreases in pressure until the discharge is extinguished. On the other hand, the characteristic for the present pump is shown at **31**. It is seen from characteristic **31** that the ion current I decreases with decreasing pressure until a certain low pressure regime is reached at which time the current tends to level out and not to decrease further with decreases in the pressure. Thus, in the very low pressure regime, the discharge current I is increased as compared to the prior open cell geometry. This facilitates starting of the ion pumps in the low pressure regime and permits the pump to operate down to lower pressures. It is believed that the improved low pressure ignition is facilitated by field emission from the posts **6**. It has been observed that the pump discharge readily strikes with anode potentials on the order of 3,000 v. at pressures less than 3×10^{-11} torrs.

Although the ion pump of the present invention has been described employing a pair of cathode projections **6** extending into the discharge anode passageway from opposite ends, this is not a requirement. If desired, only one cathode projection need extend into the discharge passageway. However, the pumping speed will be reduced compared to a geometry employing cathode projections extending from opposite ends of the discharge passageway.

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 interrupted as illustrative and not in a limiting sense.

What is claimed is:

1. In an ion getter vacuum pump apparatus, means forming an anode structure having at least one discharge passageway therein, means for producing a magnetic field within and generally axially directed of said discharge passageway for magnetically confining the discharge, means forming a cathode structure spaced from said anode structure, said cathode structure being made of a getter material, means forming an insulative structure for insulating said anode structure from said cathode structure to permit an electrical potential to be applied between said anode and cathode structures to establish a magnetically confined electrical discharge therebetween to produce ions for bombarding said cathode structure to sputter cathode getter material onto collecting surfaces within the pump for getter gases within the vacuum pump apparatus, said cathode structure including at least one projection of getter material extending from said cathode structure coaxially of said discharge passageway in said anode structure and from which getter material is sputtered in use, the improvement wherein said cathode projection extends into said discharge passageway in said anode structure terminating at a point substantially less than half-way along the length of said discharge passageway to define in said discharge passageway a magnetron discharge region and a hollow anode magnetically confined Penning discharge region, said magnetron discharge region being defined between said cathode projection and the walls of said discharge passageway, and said hollow anode Penning discharge region being defined by that portion of said discharge passageway which does not contain said cathode projection.

2. The apparatus of claim **1** wherein said cathode projection is elongated and made of a body centered cubic material, whereby the sputtering from the projection is increased.

3. The apparatus of claim **2** wherein said cathode projection is made of tantalum, whereby the solubility of hydrogen in the getter material sputtered from said projection has a relatively high value as compared to molybdenum.

4. The apparatus of claim **1** wherein said cathode projection is an elongated cylindrical post coaxially aligned with the axis of said discharge passageway in said anode structure.

5. The apparatus of claim **4** wherein said cathode post has a diameter less than 20% of the diameter of the coaxial discharge passageway and a diameter greater than 0.030 inch.

6. The apparatus of claim **5** wherein said cathode structure includes a plate having said cathode post conductively affixed thereto and extending therefrom into said anode discharge passageway, and wherein said anode passageway has uniform cross sectional dimensions over substantially its entire length.

7. The apparatus of claim **1** wherein said anode structure includes a plurality of parallel discharge passageways, and said cathode structure includes a plurality of elongated cathode projections extending coaxially into said discharge passageways and terminating at points within said discharge passageways substantially less than midway along the length of said passageways.

8. The apparatus of claim **1** wherein a pair of said cathode projections are elongated post structures and extend into said discharge passageway from opposite ends of said passageway in coaxial alignment therewith and with each other, each of said elongated cathode projections terminated within said discharge passageway at points substantially less than midway along the length of said passageway.

9. The apparatus of claim **8** wherein said cathode structure includes a pair of plates disposed on opposite sides of said anode and having said elongated cathode post structures projecting therefrom in coaxial alignment with said discharge passageways and terminating at a point substantialy less than halfway along the length of said discharge passageway, said discharge passageways being open at both ends and extending through said anode with the open ends of said discharge passageways terminating in a pair of planes axially spaced from the plane of said cathode plates, and said elongated cathode posts including pairs of said posts extending into a plurality of said discharge passageways from both ends thereof to define a plurality of discharge passageways having magnetically confined Penning discharge regions in the central regions of said discharge passageways between the opposed free ends of a pair of opposed cathode posts and defining a pair of magnetron discharge regions in the opposite end regions of said discharge passageways near the open ends thereof.

10. The apparatus of claim **9** wherein said cathode posts are made of tantalum.

References Cited

UNITED STATES PATENTS

2,993,638	7/1961	Hall et al.	230—69
3,239,133	3/1966	Noller	230—69

ROBERT M. WALKER, Primary Examiner

U.S. Cl. X.R.

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