

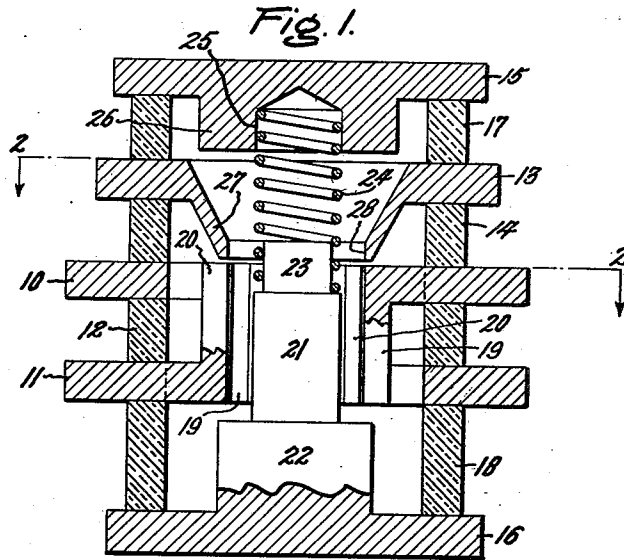
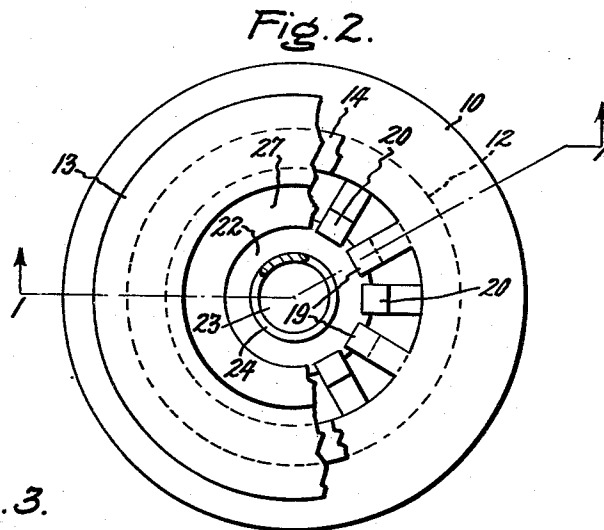
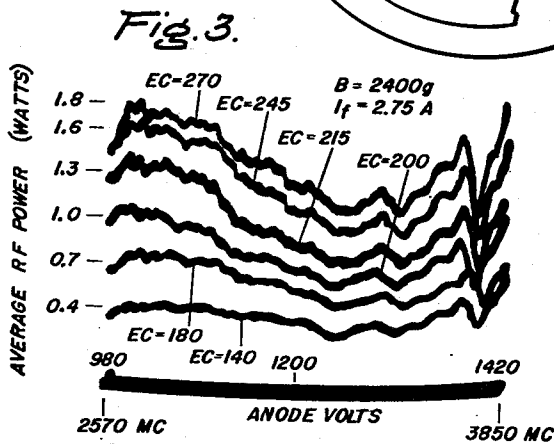
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VOLTAGE TUNABLE MAGNETRON WITH CONTROL ELECTRODE

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1

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VOLTAGE TUNABLE MAGNETRON WITH CONTROL ELECTRODE

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7 Claims. (Cl. 315—39.73)

The present invention relates to an improved magnetron tunable by variation of the anode-cathode voltage and more particularly to such a magnetron having a control electrode for determining the power level at which the voltage tunable operation takes place.

In our copending application, Serial No. 169,712, filed June 22, 1950, which is now U. S. Patent 2,774,039, granted December 11, 1956, entitled "Magnetron and Systems Therefor" and assigned to the same assignee as this application, is described and claimed a method and apparatus for tuning a magnetron system over a substantial frequency range by varying the anode voltage. As outlined in that application, we have found that the oscillating frequency of a magnetron will vary directly with the direct current voltage applied to the anode-cathode circuit if the rate of increase of the high frequency voltage with respect to an increase in the direct current anode-cathode voltage is properly controlled. We have further found that the variation of the high frequency voltage with direct current anode-cathode voltage may be kept within the desired relationship if the anode circuit is heavily and uniformly loaded over the entire tuning range and at the same time the number of electrons in the interaction space is suitably limited. In our copending application, Serial No. 504,049, filed April 26, 1955, entitled "Magnetron Device" and assigned to the same assignee as this invention, is described and claimed an improved magnetron structure which is simple, sturdy, relatively easy to reproduce with accuracy and which possesses electrical characteristics compatible with the requirements for voltage tuning.

In accordance with one feature of our latter aforementioned application, the emitting cathode is partly or entirely longitudinally displaced from the anode array. The greater the displacement the more effective is the limitation of the space charge and the less the likelihood of instability due to back heating of the cathode. The displacement, however, tends to limit the output high frequency power level that may be attained so that the actual position of the cathode is a compromise.

The present invention is in the nature of an improvement over the inventions described and claimed in our aforementioned applications and relates particularly to the provision of means for effecting operation of the voltage tunable magnetron at different selected output power levels while retaining the advantages of having the emitting cathode displaced from the anode circuit. More specifically, the magnetron is provided with an emitting cathode area physically outside of the oscillatory circuit, of which the anode is a part, and surrounded by a control electrode for determining the space charge within the anode and as a result the output power level. The end of the control electrode is physically very close to the anode, in an axial direction, and is shaped to provide an axial component of field to assist in injecting the electrons into the anode while at the same time keeping the electrons collected by the control electrode at a minimum.

It is accordingly an important object of our invention

2

to provide a new and improved voltage tunable magnetron for operation at different adjustable power levels.

Further objects and advantages of our invention will become apparent as the following description proceeds, reference being had to the accompanying drawing in which Fig. 1 is an elevational view in section of a magnetron device embodying our invention, the planes of section being shown by the line 1—1 of Fig. 2,

Fig. 2 is a sectional view taken along the line 2—2 of Fig. 1, and

Fig. 3 is a family of curves showing the power output at different values of voltage of the control electrode as the anode voltage and, as a result, the operating frequency are varied over a substantial range.

Referring now to the drawing, we have shown a specific magnetron device embodying the features of our invention. The envelope of the device is made up of a stack of alternately arranged metal and ceramic members, the metal members forming the terminals of the device and the ceramic members forming the insulating spacers therefor. As shown in the drawing, the terminal members include a pair of annular anode terminals 10 and 11, separated by a ceramic cylinder 12 and an annular grid terminal 13, separated from the anode terminal 10 by means of a ceramic cylinder 14. The envelope is completed by a pair of disk-shaped metal end members 15 and 16 separated respectively from the grid terminal 13 and anode terminal 11 by ceramic insulators 17 and 18.

The magnetron device illustrated is of the interdigital type and the anode assembly includes two sets of axially extending anode segments alternately arranged in a cylindrical array, supported concentrically within the envelope by anode terminals 10 and 11. Alternate segments 19 and 20 are connected to a different one of the annular anode terminals 10 and 11 so that we have two groups of anode segments alternately arranged in the array with each group connected to one of the terminals 10 or 11. The segments are slightly separated to provide axially extending interaction gaps. As is well understood, it is the interaction between the high frequency fields across these gaps and the rotating and bunched space charge that effects the transfer of energy from the space charge to the oscillatory circuit of the anode.

In the specific embodiment illustrated, the electrons of the rotating beam are emitted from an area longitudinally displaced from the array of anode segments, and the entrance of the electrons into the region of the interaction gaps is under the control of a control electrode. As shown in the drawing, the cathode includes a non-emitting cylindrical post 21 supported from the end terminal 16 concentrically within the array of anode segments. As shown, the post 21 is formed integrally with an enlarged extension 22 of the end terminal 16, the extension forming an end shield for the interaction space. The free end of the non-emitting cathode 21 is provided with a portion 23 of slightly reduced diameter in the region of the upper end of the anode assembly and provides a support for one end of a thoriated tungsten spiral 24 which provides the electron emitting cathode. The spiral 24 has an inner diameter equal to that of the reduced end portion 23 and an outer diameter equal to the non-emitting portion 21 of the cathode. The other end of the spiral is received within a recess 25 formed in an extension 26 of the end terminal 15. It is apparent from the foregoing description that the end terminals 15 and 16 provide the terminals for the filament supply and that the terminal 16 may also provide the direct current cathode terminal. It is also apparent that the emitting portion of the spiral 24 terminates essentially at the end of the reduced portion 23 of the cathode support since the turns which overlie this portion are effectively short-circuited. It will be readily apparent, therefore, that the

emitting portion of the cathode in the specific embodiment illustrated is entirely outside or longitudinally spaced from the interaction space of the oscillatory circuit. While a thoriated tungsten spiral is a preferred form of emitting cathode for the magnetron device, it will be apparent that the other emitting cathode structures may be used, such as continuous surface coated with an oxide. This is particularly true in the construction embodying the present invention where the emitting surface is outside of the interaction space and not subjected to backheating by returning electrons.

The anode segments are preferably coextensive in axial length or, in other words, the free ends of one set of segments terminate in the same plane as the fixed ends of the remaining set of segments. This reduces the coupling that would exist between the cathode and anode if the axial overlap of the segments of the two sets were less than 100%.

In accordance with an important feature of the present invention, electrons emitted by the cathode portion 24 that enter the interaction space between the non-emitting cathode portion 21 and the cylindrical array of anode segments 19 and 20 are under the control of a control electrode 27 which may to advantage be formed integrally with the control grid terminal 13. As illustrated, the control electrode is generally frusto-conical in shape having an inner surface which is spaced progressively closer to the emitting electrode portion 24 in an axial direction toward the anode assembly. In operation, the control member is maintained at a positive voltage with respect to the cathode so that an axial component of velocity toward the interaction space is imparted to the electrons. The control member terminates in closely spaced relation with the anode assembly and, as illustrated, is provided with a short cylindrical surface 28 adjacent the anode and having the same diameter as the inner surface of the anode segments.

The particular shape of the control electrode and its spacing from the anode contributes substantially to its effectiveness in injecting a substantial number of electrons into the interaction space between the cold cathode portion 21 and the anode segments. This is particularly desirable in voltage tunable operation since under the conditions existing during such operation, the high frequency fields between adjacent anode segments are weak as compared to those existing in tank tuned operation. In a specific embodiment of our invention, the wall of the control electrode extends at an angle of 30° with respect to the axis of the cone and the cylindrical portion 28 of the control electrode has an axial dimension of 20 mils. The spacing between the face of the anode and the end of the control electrode is 10 mils. It will be noted from the drawing that the cylindrical portion of the control electrode is preferably radially opposite a non-emitting portion of the cathode.

While the specific configuration of the control electrode illustrated is particularly desirable both from the standpoint of manufacture and from the effect on the control characteristics thereof, it is apparent that variations in shape and dimensions may be made without departing from some of the objectives of the present invention. For example, it is possible to provide other shapes in which the control electrode provides an axial component of field and which is spaced more closely to the cathode at the side thereof axially nearer to the anode.

While the specific form of magnetron device described above may be assembled in accordance with methods well known in the art, it may to advantage be evacuated and the parts forming the envelope thereof bonded together in a single operation. For example, the ends of the ceramic cylinders may be coated with titanium hydride and the parts arranged in a stack and suitably held together by a clamp. The assembly may then be placed in a bell jar (not shown) and evacuated. Within the bell jar, there is also a solder pot containing a suitable solder, such as

lead. Means for heating the discharge device and solder pot may include a cylindrical oven of suitable metal, such as tantalum. The oven is raised to a suitable temperature, such as 800° C., by induction heating and the tube degassed and evacuated. The solder pot is then elevated or the tube lowered to immerse a part of the tube (which is supported with its axis horizontal) into the molten solder. The solder follows up around the joints between the ceramic and metal parts and quickly wets those parts which have been painted with titanium hydride. This method of sealing does not form a part of our present invention but is described and claimed in copending Beggs application, Serial No. 464,077, filed October 22, 1954, entitled, "Metallic Bond" and assigned to the same assignee as this invention.

The manner in which magnetrons embodying our invention operate will be better understood by a consideration of the family of curves illustrated in Fig. 3 and showing the different high frequency power outputs obtained with different constant values of control electrode voltage, while the anode voltage and, as a result, the operating frequency are varied over a substantial range. The curves shown in Fig. 3 are reproduced from a multiply exposed photograph, one exposure being made for each different value of control voltage. As illustrated in Fig. 3, the axial magnetic field produced by suitable magnets or electromagnets (not shown) was adjusted to a value of 2400 gauss and the filament current to a value of 2.75 direct current amperes. With each value of control voltage, the anode voltage was swept through a range of 980 to 1420 volts. This voltage change was accompanied by a change in operating frequency of 2570 megacycles to 3850 megacycles. Different values of control voltage between 140 and 270 volts were employed and the average high frequency power output for these control voltages varied from .4 watt to 1.4 watts. It will be noted that at the lower values of control voltage and the lower power output that the power output remained substantially constant over the entire range of variation of anode voltage and operating frequency. While there is some variation of the power output with anode voltage change at the higher values of control voltage and high frequency power output, this variation is within acceptable limits.

The present invention provides a magnetron which is well suited to voltage tuning and which provides the particularly desirable combination of cathode and control member structure for use in this type of operation with the result that frequency variation over a wide range in accordance with the variation in anode-cathode voltage may be provided at an adjustable, relatively constant high frequency power output.

While the foregoing, illustrated embodiment of our invention has been described as particularly applicable to a voltage tunable magnetron operation, it is also useful in connection with continuous wave or pulse operation, the control electrode being utilized to control the power output.

While we have shown and described a particular embodiment of our invention, it will be apparent to those skilled in the art that modifications may be made without departing from our invention and we, therefore, aim by the appended claims to cover any such modifications as fall within the true spirit and scope of our invention.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. A magnetron comprising an anode circuit including a plurality of segments supported in a cylindrical array in mutually spaced relation, a non-emitting electrode supported concentrically within the opening defined by said segments, an electron emitting electrode spaced axially from said non-emitting electrode and a control electrode surrounding said emitting electrode, said control electrode having a frusto-conical interior surface terminating adjacent one end of said array.

5

2. A magnetron comprising an anode circuit including a plurality of segments supported in a cylindrical array in mutually spaced relation, a non-emitting electrode supported concentrically within the opening defined by said segments, an emitting electrode spaced axially from said non-emitting electrode and a control electrode surrounding said emitting electrode, said control electrode having an interior surface tapered inwardly toward said array and terminating adjacent one end of said array.

3. A magnetron comprising an anode circuit including a plurality of segments supported in a cylindrical array in mutually spaced relation, a non-emitting electrode supported concentrically within the opening defined by said segments, an emitting electrode spaced axially with respect to said non-emitting electrode and a control electrode surrounding said emitting electrode, said control electrode having an inner cylindrical surface of short axial length terminating in closely spaced relation to one end of said array and additional inner surface axially more remote from said array and of larger diameter than said cylindrical surface.

4. A magnetron device comprising an anode circuit including a pair of axially spaced coaxial ring-like anode terminals and a plurality of segments supported in a cylindrical array from said terminals in mutually spaced relation with alternate segments connected to one of said terminals and the remaining segments connected to the other of said terminals, a non-emitting electrode supported concentrically within the opening defined by said segments, an emitting electrode spaced axially from said non-emitting electrode, a pair of mutually insulated terminals positioned on opposite sides of said anode terminals, means connecting said emitting and non-emitting electrodes in series and with said last-mentioned pair of terminals within said device, and a control electrode surrounding said emitting electrode, said control electrode terminating adjacent one end of said array.

5. An electric discharge device comprising four insulating rings arranged in a stack, three ring-shaped metal terminals each interposed between adjacent ends of different pairs of said insulating rings, a pair of end terminal members at opposite ends of said stack, a cylindrical array of anode segments supported from two of said ring-shaped terminals within said insulating rings

6

with alternate segments connected to one of said pair of ring-shaped terminals and the remaining segments connected with the other of said pair of ring-shaped terminals, a spiral cathode supported at opposite ends thereof from said end terminals, and a control electrode surrounding said spiral cathode and supported from the third of said ring-shaped terminals.

6. An electric discharge device comprising four insulating rings arranged in a stack, three ring-shaped metal terminals each interposed between adjacent ends of different pairs of said insulating rings, a pair of end terminal members closing opposite ends of said stack, a cylindrical array of anode segments supported from two of said ring-shaped terminals within said insulating rings with alternate segments connected to one of said pair of ring-shaped terminals and the remaining segments connected with the other of said pair of ring-shaped terminals, a conductive cylindrical non-emitting cathode member supported concentrically within said array of anode segments from one of said end terminals, an emitting cathode supported from the other of said end terminals, and a control electrode surrounding said emitting cathode and supported from the third of said ring-shaped terminals.

7. An electric discharge device comprising four insulating rings arranged in a stack, three ring-shaped metal terminals each interposed between adjacent ends of different pairs of said insulating rings, a pair of end terminal members at opposite ends of said stack, a cylindrical array of anode segments supported from two of said ring-shaped terminals within said insulating rings with alternate segments connected to one of said pair of ring-shaped terminals and the remaining segments connected with the other of said pair of ring-shaped terminals, a conductive cylindrical non-emitting cathode member supported concentrically within said array from one of said end terminals, an emitting cathode supported from the other of said end terminals, and a hollow frustoconical control electrode surrounding said emitting cathode and supported from the third of said ring-shaped terminals with the smaller end thereof adjacent one end of said array.

No references cited.