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HIGH FREQUENCY CROSSED-FIELD DEVICE
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Fig. 1.

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This invention relates to an electron discharge apparatus of the type commonly called magnetrons useful to produce high frequency electromagnetic energy.

Magnetrons are known which comprise as essential elements, a hollow anode structure generally of circular outer periphery, a plurality of vanes protruding radially inwardly from the periphery of the anode and a cathode extending axially along the interior of the anode along a central portion thereof. Adjacent vanes comprise resonant cavities and the frequency of the resonant cavities is determined by the specific dimensions thereof. A direct potential, negative with respect to the anode is applied to the cathode for attracting electrons from the cathode to the anode and a constant magnetic field transverse to the electric field and substantially parallel to the axis of the cathode is applied to control the movement of the emitted electrons.

In certain applications of magnetrons it is important as well as desirable to minimize the size and weight thereof for a given frequency of operation. For operation at low voltages, e.g., approximately 100 to 1000 volts between cathode and anode, and at low frequencies, e.g., approximately 200 megacycles or less, vane-type magnetron anodes of conventional construction are quite large in diameter since the cavity depth need be of the order of a quarter wave length at the operating frequency. Reducing such length has the effect of reducing the inductance of the cavity between vanes since such inductance is proportional to the product of the characteristic impedance of adjacent vanes and the length of the vanes. Thus, a simple reduction of such lengths would greatly alter the frequency of operation of the magnetron.

It is known to compensate for the adverse effects of a reduction in the depths of these cavities and consequently the anode diameter, by replacing the vanes with relatively narrower vanes of higher impedance thus retaining the necessary circuit parameters for operation at the desired frequency. However, since considerable heat is generated within the interior of a magnetron, the reduction of vane cross-sectional area produces the undesirable result that heat conduction and heat dissipation through the vanes from the magnetron interior is decreased whereby the power capabilities of the magnetron are likewise decreased. Thus, the reduction in size of the magnetron is made at the expense of limiting the power output of the device and frequently no net benefit results.

It is accordingly a primary object of this invention to facilitate a reduction in size and weight of a resonant anode, particularly a vane-type, magnetron oscillator without adversely affecting the power capabilities thereof.

It is another object of this invention to effect an increased characteristic impedance between vanes of a magnetron while reducing the length thereof and maintaining the cross-section dimensions the same.

Other and further objects and advantages of this invention will become apparent from a consideration of the following detailed description thereof considered with the accompanying drawings in which

FIGURE 1 is a cross-sectional elevation of a magnetron structure according to my invention in its entirety.

FIGURE 2 is a partial plan view taken along section 2—2 of FIGURE 1, and

FIGURES 3, 4 and 5 are elevational side views showing details of various vanes utilized in the magnetron of FIGURE 1 according to my invention.

In accordance with a feature of my invention the foregoing objects are achieved by maintaining the cross-sectional area of vanes of a vane-type of magnetron and reducing the radial length thereof and by axially staggering or misaligning the vanes with respect to adjacent vanes to establish an overlap of adjacent vanes of only a fraction of their total facing area. That is, the circumferentially projected area of any vane covers only a fraction of the area of an adjacent vane. In accordance with this arrangement, the inductance of the cavity between vanes is maintained since the characteristic impedance is increased by the decrease in overlapping vane area sufficiently to compensate for the reduction of electrical length of the cavity. The capacity between cathode and vanes is maintained by not staggering the vane tips. This capacity and the vane inductance essentially determine the resonant frequency.

Referring now to the drawing, FIGURE 2 represents generally the entire magnetron structure embodying the details of my invention, including an anode represented generally at 12 and a cathode structure centrally disposed with respect to the anode and represented generally at 14. The anode includes a ring 16 having notches along the interior thereof for accommodating edges of a plurality of radially positioned vanes 18 which are set forth and described in considerable detail below. The anode and cathode structures are enclosed in a housing 19 having a cylindrical portion 22 surrounding ring 16, a radial portion 24 in abutment with one end of the ring and an axial portion 26 joined with a reduced axial portion 28 forming a tapered portion 30 extending therebetween. The free end of portion 22 is covered with an end piece 32 secured to the portion 23 at its outer periphery.

For providing electron emission, cathode 14 includes a hollow drum 36 mounted on a cup 38 shown inverted in FIGURE 1, by a pair of brackets 40 and 42 secured to the cup and engaging the inner sides of the end portions 44 and 46 of the drum. The cathode may be of any suitable material but preferably is made of nickel having an electron emission enhancing coating thereon such as barium oxide. The brackets 42 are also provided with notches for accommodating a plurality of ceramic columns 45, spaced from each other and extending completely about the brackets and a heater wire 50 is helically wound about the columns collectively. The heater wire is closely spaced from drum 36 so as to readily transfer heat thereto and facilitate electron emission by the drum. For preventing stray emission from the cathode, a pair of end hats 52 and 54 are secured to respective ends of the cup 38 and extend radially therefrom to the radial extremity of the drum.

The cathode structure is supported by a post represented generally at 56 which comprises a plurality of stacked elements. At its upper end, post 56 includes an annular metal ring 58 having its outer periphery joined with the open end of cup 38 and its inner periphery joined to one end of a tubular conducting member 60, the other end of which has a pair of radial flanges 62 and 64 joined by an axial portion 66. A tubular member 72 is shown in FIGURE 1 and joins a frusto-conical insulator 68 which in turn supports sleeve 28 by its inwardly directed flange 70. A second conductive member 72, also having a pair of flanges 74 and 76 joined by an axial portion 78 is spaced from the tube 60 by an annular insulator 80 disposed between flanges 62 and 74 and another tubular member 82 spanning a flange 84 is supported in spaced relation to member 72 by an annular insulator 86. Each of the insulators is bonded to the members in contact therewith to provide a relatively rigid unitary and hermetically sealed structure.
Electrical connections to the heater wire 50 are provided by leads 88 and 90 extending from respective ends of the wire to contact with members 72 and 82, respectively, and exterior connections thereto are facilitated by leads 92 and 94, also contacting members 72 and 82.

Cathode drum 58 is provided with exterior connections through lead 96, tube 60, member 56, cup 38, and brackets 40 as indicated.

For immersing the space between cathode and anode in a magnetic field, a pair of electromagnets having respective cores 98 and 100 and respective energizing coils 102 and 104 excitable in any suitable manner are provided.

A tubeulation 103 may be formed at the end of post 56 in communication with the interior of the post and cup 38 is provided with an opening 105 establishing communication with the interior of the magnetron for evacuating the same.

In accordance with an important feature of my invention the vanes 18 are of different types and are differently disposed in the anode. A first type of vane is illustrated in FIGURE 3 and designated 18A. An outer edge 106 of a relatively narrow portion 108 of the vane having a predetermined height substantially equal to the height of the ring 16, is received in a notch 17 of the ring and an intermediate portion 110 of substantially equidistantly reduced in height on opposite upper and lower sides thereof with respect to portion 108. An inner portion 112 of this vane is enlarged at upper and lower edges with respect to portion 110 and is provided with notches for accommodating straps either in contacting relationship or noncontacting relationship. A pair of these notches 114 and 116 receive in contact, respective straps 118 and 120 of the magnetron and a pair of further notches 122 and 124 accommodate a pair of straps 125 and 120 in noncontacting relationship as shown in FIGURE 1.

A plurality of further vanes identical to vane 18A are similarly disposed at equally angularly spaced points about the magnetron and are similarly joined to straps 118 and 120 at upper and lower edges of portion 112.

For simplicity, such further vanes are designated in FIGURE 2 by the same number 18A.

Further in accordance with my invention, a second type of vane is illustrated in FIGURE 4 and designated 18B. This vane includes an outer edge 130 of a relatively narrow portion 132 having a predetermined height substantially equal to the height of the ring 16 and being receivable in a notch 17 of the ring. An intermediate portion 134 of core 18B is reduced in height to portion 132 from the upper side thereof and is formed integral with portion 132. An inner portion 136 of substantially the same height as portion 132 is formed integral with portion 134 and is provided with notches at its upper and lower edges for accommodating the straps in conducting and nonconducting relationship. Notches 138 and 140 at respective ends, contact straps 126 and 128, respectively, while notches 142 and 144 accommodate straps 118 and 120 in noncontacting relationship. A plurality of vanes identical to vane 18B are disposed in the magnetron and each is spaced at an intermediate location between alternate pairs of vanes 18A. Thus, the magnetron contains one-half as many vanes 18B as it does 18A.

A third type of vane in magnetron 10 is illustrated in FIGURE 5 and designated as 18C. This vane including an outer edge 146 of a relatively narrow portion 148 having a predetermined height substantially equal to the height of the ring 16 and being receivable in a notch 17 of the ring. An intermediate portion 150, reduced in height with respect to portion 148 from the lower side thereof as seen in FIGURE 5 is formed integral with portion 148 and an inner portion 152 of substantially the same height as portion 148 is formed integral with portion 150. The inner portion 152 is provided with notches at its upper and lower edges for accommodating the straps in contacting and noncontacting relationship as the case may be. Notches 154 and 156 contact strap 126 and 128, respectively, at upper and lower sides of portion 152, respectively, and notches 158 and 160 accommodate straps 118 and 120 in noncontacting relationship. A plurality of vanes identical to vane 18C are disposed in the magnetron and each is equidistantly spaced from individual vanes 18C and notches 158 therebetween. Thus, the arrangement of vanes is such that they appear circumferentially in the order 18A, 18B, 18C, 18A, 18B, 18A, 18C, etc. Thus, there are also one half as many vanes 18C as there are vanes 18A in the magnetron.

In this arrangement it is observed that in considering any two adjacent vanes, the area of one projected circumferentially on the other is substantially less than the entire area thereof. In the present circumstances, the projected area is approximately one half of the total area of the vane although it is contemplated that other ratios of projected area may be used. Accordingly, since the characteristic impedance of a line formed by adjacent vanes is increased by a reduction in the projected area on adjacent line members, the line herein formed by adjacent vanes is reduced by reason of reduced area of projection as compared to the vanes 18A. The inner vanes may be reduced to similarly reduce the over-all diameter of the magnetron without altering the inductance of the line formed by adjacent pairs of vanes or without affecting the frequency of resonance of the cavities formed between adjacent pairs of vanes. The cross-sectional area of any of the vanes 18A, 18B or 18C may, under these circumstances, be maintained whereby the power dissipation capabilities of each of the vanes is retained and the power capabilities of the magnetron is also maintained. It is still further to be observed that this invention is equally applicable to other types of magnetron structures such as those having a hole and slot anode structure or in linear magnetrons wherein the anode segments are arranged in a linear rather than circular array.

The output of the magnetron may be taken from symmetrically disposed vanes such as 18A and applied to a coaxial transmission line having respective outer and inner conductors 162 and 164. The outer conductor 162 is joined at its inner end with the inner conductor of end piece 32 and to facilitate the transfer of the output energy of the magnetron to the coaxial line, the inner end of inner conductor 164 is connected to a control portion of a plate 166 which has legs such as shown at 168 and 170 cooperatively joined to the edges of vanes 18A along intermediate portions thereof. The plate has other legs connected to each of the vanes 18A which are not shown in FIGURE 1 of the drawings but are shown in section in FIGURE 2.

For shielding the cathode structure of the magnetron from the plate 166 and other output circuitry, a hood 172 of generally disc shape, extends completely over the output end of the magnetron. The hood 172 is secured about its periphery to housing 20 and is provided with openings as shown at 174 and 176, for example, to accommodate each of the plate legs in nonconducting relationship.

For maintaining the interior of the magnetron hermetically sealed from ambient space, a seal is provided between outer conductor 162 and the inner conductor 164 of the coaxial output line. This seal includes a sleeve 178 sealingly attached within an outer portion of conductor 162 and has an inwardly directed flange portion 180 to provide a seal for a frustated, hollow, conical, insulating member 182. A similar seal is provided for the inner end ported portion 182 by a concentrically directed flange 184 at the end of an extension 186 of the inner conductor 164. The member 182 is sealed to each of these flanges and to impart strength and rigidity to
the seal, annular members 188 and 190 are bonded to the sides of the flanges 180 and 186 opposite to the sides to which the conical member 184 is attached.

For preventing escape of high frequency energy generated by the magnetron from the lower portion thereof, a choke effective at the frequencies generated is established by an annular, conical-shaped member 194 extending from its inner attachment to strap 128 to a point near the flange portion 86 of housing 20 and being spaced from tapered portion 39 of the housing.

While the present invention has been described by reference to particular embodiments thereof, it will be understood that numerous modifications may be made by those skilled in the art without actually departing from the invention. I, therefore, aim in the appended claims to cover all such equivalent variations as come within the true spirit and scope of the foregoing disclosure.

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

1. An electrical discharge apparatus for generating high frequency electromagnetic waves comprising an anode having a plurality of conductive convergent vanes disposed in a circular array, a cathode equidistantly spaced from each of said vanes to provide an interaction region in which each vane having an inductive surface portion with each side thereof having a predetermined surface area, a portion of said predetermined area being the total thereof being aligned with respect to the inductive portion of an adjacent vane to establish a projected area on said portion of said adjacent vane less than the said predetermined area thereof, whereby the characteristic impedance presented by a pair of adjacent vanes is greater than that which would be presented by a pair of aligned vanes.

2. A magnetron apparatus comprising an anode including a plurality of spaced vanes, each of said vanes having an inductive surface portion intermediate its length offset with respect to the intermediate inductive surface portion of an adjacent vane to establish a projected area on the intermediate inductive surface portion of the adjacent vane less than its entire surface area.

3. A magnetron apparatus comprising an anode including a plurality of spaced vanes substantially perpendicular to a plane, said vanes being symmetrically disposed in a circular array, each vane having an intermediate inductive surface portion of substantially the same surface area, the intermediate inductive surface portion of adjacent vanes being offset from said plane and with respect to each other whereby the circumferentially projected area of any intermediate inductive surface portion of any vane on the intermediate inductive surface portion of an adjacent vane is less than the entire area thereof.

4. A magnetron apparatus comprising an anode having a plurality of spaced convergent vanes having extremities between and being perpendicular to a pair of planes, a first group of said vanes having intermediate portions equidistantly spaced from each of said planes, a second group of vanes having intermediate surface portions nearer one of said planes than the other thereof and a third group of said vanes having an intermediate surface portion nearer the other plane than the first thereof.

5. A magnetron apparatus comprising an anode having a plurality of spaced, convergent vanes having extremities between and parallel to a pair of planes, a first group of said vanes being symmetrically disposed with respect to each other and having an intermediate portion equidistantly spaced from each of said planes, a second group of said vanes being symmetrically disposed with respect to each other and having an intermediate portion nearer one of said planes than the other thereof, each of the vanes of said second group having a predetermined spacing from alternate vanes of said first group, a third group of said vanes having an intermediate portion nearer the other of said planes than the first thereof and being symmetrically disposed with respect to each other, each of the vanes of said third group being equidistantly spaced between a vane of said second group and a vane of said first group.

6. A magnetron apparatus comprising an anode including a plurality of spaced, convergent vanes, each of said vanes having an inductive surface portion intermediate its length, the projected area of each inductive portion of each of said vanes on the inductive portion of an adjacent vane being less than the total area thereof.

7. A high frequency electron discharge apparatus comprising an anode including a plurality of cavities separated by vanes, a cathode disposed equidistantly from the nearest edges of each of said vanes, each vane having an intermediate portion between its said edge and the end of the vane remote therefrom, the area of the intermediate portion of any vane projected on the surface of the intermediate portion of an adjacent vane being less than the total surface area of the projected vane.

8. A high frequency electron discharge apparatus comprising an anode including a plurality of cavities separated by vanes, a first plurality of said cavities being identical and spaced to form a boundary for some of said cavities, a second plurality of said vanes being identical and spaced to form another boundary for some of said cavities, each of said second plurality of said cavities being equidistantly spaced from a pair of vanes of said first plurality, a third plurality of identical vanes being identical and spaced to form a boundary for some of said cavities, each of the vanes of said third plurality being equidistantly spaced from a pair of vanes of said first plurality.

9. An apparatus according to claim 8 wherein said third plurality is equal to said second plurality and is equal to one half said first plurality.

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