Aug. 29, 1961 P. W. CRAPUCHETTES 2,998,544

MAGNETRON CATHODE

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Fig. 1

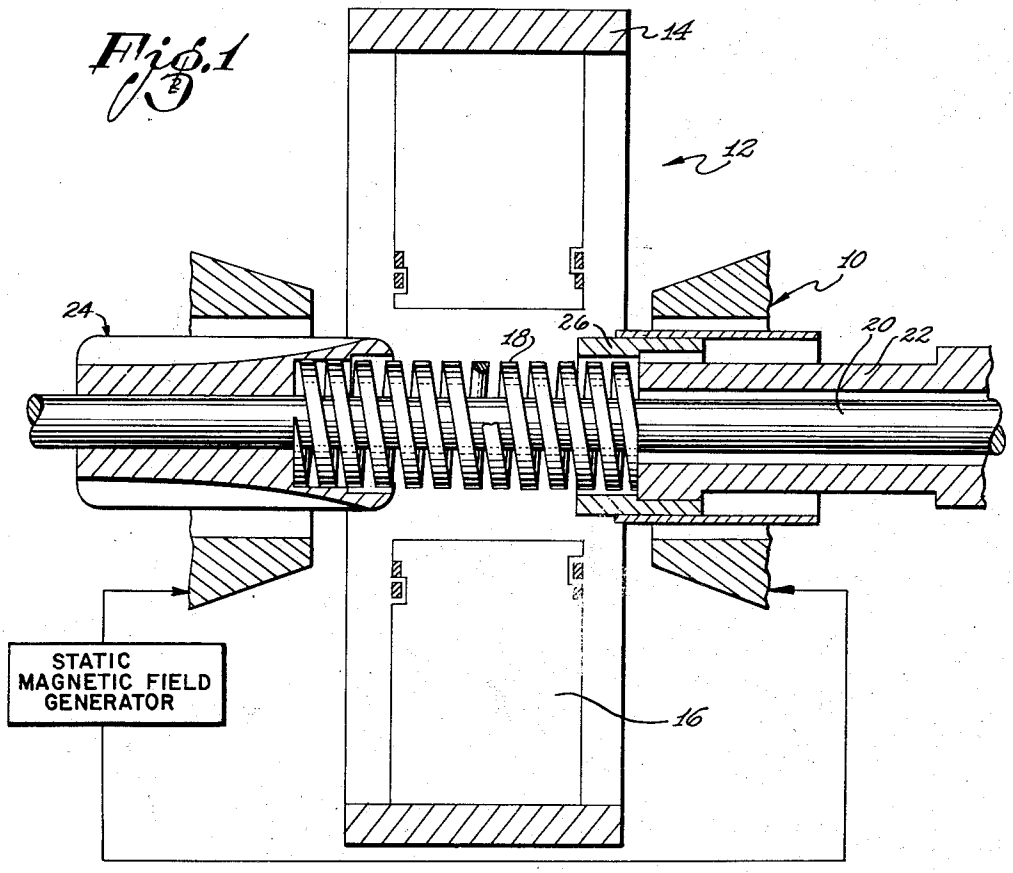
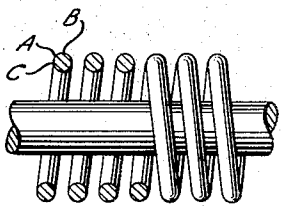



Fig. 2




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# MAGNETRON CATHODE

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6 Claims. (Cl. 315—39.51)

This invention relates to magnetron cathodes, and more particularly to filamentary high current density cathodes for use in magnetrons. This application is a continuation of U.S. patent application Serial No. 339, 858, filed March 2, 1953, now abandoned.

The cathode in a magnetron must serve two important functions. Firstly, it must supply the stipulated cathode current density under conditions of complete or very nearly complete space-charge limitation, and secondly, it must dissipate most of the back-bombardment electrons without harm to itself. In general, magnetron cathodes employ one of three basic types of electron emitters, and may be classified in view thereof as (1) low-temperature oxide cathodes, (2) cold cathodes that operate by secondary emission from a material such as beryllium or silver-magnesium alloy; or (3) high temperature cathodes such as those using thoriated tungsten, tantalum, or thorium oxide. The respective properties of these three cathodes are so disparate that each finds its particular field of usefulness.

Still another feature of magnetron cathode design is the associated supporting structure, and again it is necessary to distinguish two methods of support because of the very different effects which they have on the associated magnetic circuit. In accordance with one well known technique the cathode is mounted axially, in which instance the cathode is accompanied by built-in hollow pole pieces and attached magnets, while still another structure calls for radial cathode supports which require a wider magnetic gap and are usually accompanied by a completely external magnetic structure.

This invention is directed specifically to high-temperature cathodes, such as those employing thoriated tungsten, which are supported axially with respect to the magnetron anode. In general such high temperature cathodes are constructed from a filamentary circular wire which is helically wound, and are energized through an associated coaxial line, one conductor of the coaxial line being connected to one end of the filament helix while the other conductor of the coaxial line is connected to the other end of the helix.

As pointed out hereinabove, one of the important requirements of a magnetron cathode is that it be capable of dissipating the energy of the back-bombardment electrons without harm to itself. This problem has been customarily attacked by presupposing that back-heating is an unavoidable problem, or at least one that is most difficult to solve, and then attempting to find a satisfactory method of cooling the cathode. It is thought that this is a negative approach to the solution of the problem, and accordingly, it is an object of this invention to reduce the back-heating or back-bombardment by eliminating one cause of the problem.

The strength of the magnetic field which is employed to cause the emitted electrons to bend and follow the desired path across the interaction space of a magnetron is usually calculated so that the maximum number of electrons will follow the desired path. Since the electron emitting surface of a conventional filament wire presents a wavy surface to the interaction space, however, the magnetic field will effect individual electrons differently, depending upon the point on the filament from which they are



emitted. Thus while electrons leaving from a given point on the arcuate filament surface will travel in the desired path, electrons leaving the surface from an area more distant from the axis of the helix than the given point will strike the anode surface too soon, while electrons leaving the surface from an area closer to the axis of the helix than the given point may be returned to the cathode and deliver to the cathode surface the energy obtained from the oscillation, thereby causing back-bombardment or back-heating of the cathode. Still another source of cathode back-heating is caused by the fact that the protruding wavy surface of the cathode presents a surface such that electrons emitted from the side of one turn of the helix may strike an adjacent turn at an angle having a significant velocity component directed inwardly towards the axis of the wire forming the helix. Therefore, in both cases the cause of back heating is a result of the wavy or protruding surface of the cathode filament in the interaction space. It is evident then that an ideal filament cathode is one that is made as flat and smooth as possible to permit uniform heating.

In accordance with this invention the random paths travelled by the electrons are reduced, and thus the back-bombardment is reduced, by grinding flat the exterior surface of the helically wound filament wire so that the exterior thereof defines substantially a cylinder and the cross-section of the wire defines a truncated circle. The outer surface of the cathode thus has the form of a smooth cylinder continuous except for the saparation between adjacent turns, this spacing being made as small as possible whereby a surface is presented to the interaction space which materially improves the efficiency of operation of the magnetron.

The above-mentioned and other features and objects of this invention and the manner of attaining them will become more apparent and the invention itself will be best understood, by reference to the following description of an embodiment of the invention taken in conjunction with the accompanying drawings, wherein:

FIG. 1 is a plan view, partly in section, of a portion of a magnetron employing a cathode in accordance with the present invention; and

FIG. 2 is an illustration of the cathode construction employed in the prior art.

With reference now to the drawing, there is shown in FIG. 1 a magnetron cathode assembly **10**, in accordance with the invention, which is employed for supplying electrons to an associated magnetron anode, generally designated **12**, under the influence of static magnetic field applied from a magnetic circuit, not shown. In the particular embodiment of the invention shown in FIG. 1 the anode comprises an annular member **14** and a plurality of conductive vanes **16** affixed thereto and extending radially inward to form a corresponding plurality of open-ended cavity resonators facing the cathode, only two of the vanes being illustrated for purposes of clarity. It is to be understood, however, that the invention is not limited to any one particular form of anode construction, and that the invention may be practiced with other types of magnetron anodes, such as the well known hole-and-slot type anode, for example.

Continuing with the description of FIG. 1, the cathode assembly in turn comprises a filamentary cathode **18** which is energized from a source of electrical energy, not shown, through a coaxial transmission line including an inner conductor **20** and an outer conductor **22**. As viewed in FIG. 1, conductor **20** is electrically connected to the left hand end of cathode **18** through an element **24** which is known to the art as an end hat, while the other end of the cathode is connected directly to conductor **22**. The assembly is completed by a second end hat element **26** which is connected to the periphery of outer conductor

22, the two end hats 24 and 26 each having a skirt portion which extends over the associated end of filamentary cathode 18 for confining the electron emission to the interaction space between the cathode and the anode.

In accordance with the present invention, cathode 18 comprises a self-supporting helically wound filament, the exterior surface of which is ground flat so that the helix defines substantially a smooth cylinder. Accordingly, the filament wire, which is preferably made of thoriated tungsten, has a cross-sectional configuration resembling a trunicated circle, as shown by the cutaway portion of cathode 18 in FIG. 1. The employment of a filamentary cathode with a flattened exterior, as taught by the present invention, has been found to decrease substantially the phenomenon known to the art as cathode back-heating by electron bombardment. In order to best illustrate the manner in which the magnetron cathode of the invention accomplishes this result, reference will now be made to FIG. 2, which is an elevation view, partly in section, of a conventional prior art magnetron cathode employing a filament of circular cross-sectional configuration.

As shown in FIG. 2, the conventional cathode filament of the prior art presents a wavy external surface paralleling the axis of the cathode, this surface irregularity being responsible for two different sources of cathode back-heating by electron bombardment. Firstly, in operation electrons are emitted toward anode 12 from various points on each turn of the cathode helix, as for example from points A, B and C. In general, the nature of magnetron design is such that electrons leaving from point A will travel in the desired orbit to the anode and will deliver maximum energy to the oscillations in the cavity resonators. Conversely, electrons leaving from point B may strike the anode too rapidly to provide maximum efficiency, while many of the electrons leaving from point C never do reach the anode, but are instead returned from the interaction space and strike the cathode, thereby generating heat in the cathode.

Still another source of back heating in prior art filamentary cathodes of the type shown in FIG. 2 is that high energy electrons emitted from the side of one filament turn of the helix may strike an adjacent turn of the helix before passing into the interaction space. Since these electrons may strike the adjacent turn with a substantial velocity component directed inwardly toward the center of the filament wire, it will be appreciated that considerable heat may be generated thereby. While this source of back-heating may be reduced by increasing the spacing between adjacent turns of the helix, it is immediately apparent that this solution will also decrease the current density in the interaction space and will thus decrease the potential output power of the magnetron.

Returning again to FIG. 1, it will be recognized that cathode 18 overcomes the foregoing deficiencies of the prior art filamentary cathodes and will thus minimize back-bombardment of the cathode. In addition, the use of a flattened filament will permit the turns of the cathode helix to be spaced relatively close together. Since the distance across the interaction space between the anode and cathode will be an order of magnitude larger in order to permit the emitted electrons to orbit properly and deliver maximum energy to the cavity resonators, it follows that the cathode, when viewed electrically from the anode across the interaction space, will appear as a substantially continuous cylindrical electron emitter.

Although the magnetron cathode of the invention as described hereinabove is shown to single helical filament, it will be readily appreciated that the invention may be practiced equally well with a bifilar filamentary cathode wherein current in adjacent turns flows in opposite directions in order to neutralize the magnetic field generated by the filament current. Accordingly, it is to be clearly understood that the foregoing description is made by way of example, and that the spirit and scope of the invention is to be construed only in view of the appended claims.

What is claimed as new is:

1. In a magnetron wherein the interaction between a radial electrostatic field and an orthogonal static magnetic field upon an electron discharge is employed for generating microwave energy, the combination comprising: a uniformly spirally wound thermionic cathode having a cylindrical configuration; means for mounting said cathode with the axis thereof parallel to the static magnetic field; and an anode structure including members forming a plurality of anode cavities spaced radially about said cathode winding whereby electrons emitted from the cathode and drawn toward the anode cavities are directed in arcuate paths relative to said axis by interaction with the magnetic field, said cathode being formed of a helically wound filament wire of circular cross-section that is ground after being wound in a helix, resulting in the wire having a truncated cross section configuration to define a flat electron emitting surface facing said anode cavities in order that the localized magnetic field component adjacent said filament winding produced by the passage of electrical current therethrough is substantially parallel to said static field whereby electrons emitted adjacent the edges of the flattened surface of said filament winding traverse substantially the same arcuate path as electrons emitted from the central region of the flattened surface of the filament winding.

2. A magnetron structure comprising a uniformly spirally wound thermionic cathode disposed along a given axis, an anode structure including members forming a plurality of anode cavities spaced radially about said axis and spaced from the cathode winding, and means producing a static magnetic field directed along said axis lengthwise of said spiral cathode whereby electrons being emitted from said cathode and drawn toward the anode cavities are directed in arcuate paths relative to said axis by interaction with said magnetic field, the improvement in said magnetron for reducing heating of the cathode by preventing emitted electrons being produced at any turn of the spiral winding from returning to that turn or an adjoining turn comprising: said cathode being formed of a helically wound filament wire of circular cross-section that is ground after winding in a helix resulting in the wire having a truncated cross-sectional configuration to define a flat electron emitting surface facing said anode cavities, and said static magnetic field producing means directing said magnetic field parallel to said flat electron emitting cathode surface whereby electrons being emitted adjacent the edges of the flattened surface of said filament winding traverse substantially the same arcuate path as electrons emitted from the central region of the flattened surface of the filament winding.

3. In the magnetron of claim 2, the filament wire of said cathode being wound in a plurality of closely spaced turns whereby the overall exterior of the cathode presents a relatively smooth electron emissive cylinder to the anode, and the distance between said anode and cathode being an order of magnitude larger than the spacing between adjacent turns in said cathode.

4. In the magnetron of claim 3, the distance between the cathode and anode vanes being substantially less than the diameter of the cathode helix.

5. In the magnetron of claim 4, the truncated cross-sectional configuration of said cathode being formed by grinding flat the exterior surface of a helical coil of circular cross-section filament wire.

6. In a magnetron wherein the interaction between a radial electrostatic field and an orthogonal static magnetic field upon an electron discharge is employed for generating microwave energy, the combination comprising: a uniformly spirally wound thermionic cathode having a cylindrical configuration; means for mounting said cathode with the axis thereof parallel to the static mag-

netic field; and an anode structure spaced radially about said cathode winding whereby electrons emitted from the cathode and drawn toward the anode are directed in arcuate paths relative to said axis by interaction with the magnetic field, said cathode being formed of a helically wound filament wire of truncated circular cross section having a flattened electron emitting surface facing said anode structure whereby the magnetic field component adjacent said filament winding and produced by the electrical current therethrough is substantially parallel to said static magnetic field and electrons emitted adjacent the edges of the flattened surface of said filament traverse substantially the same arcuate path as electrons emitted from the central region of the flattened surface of the filament winding.



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