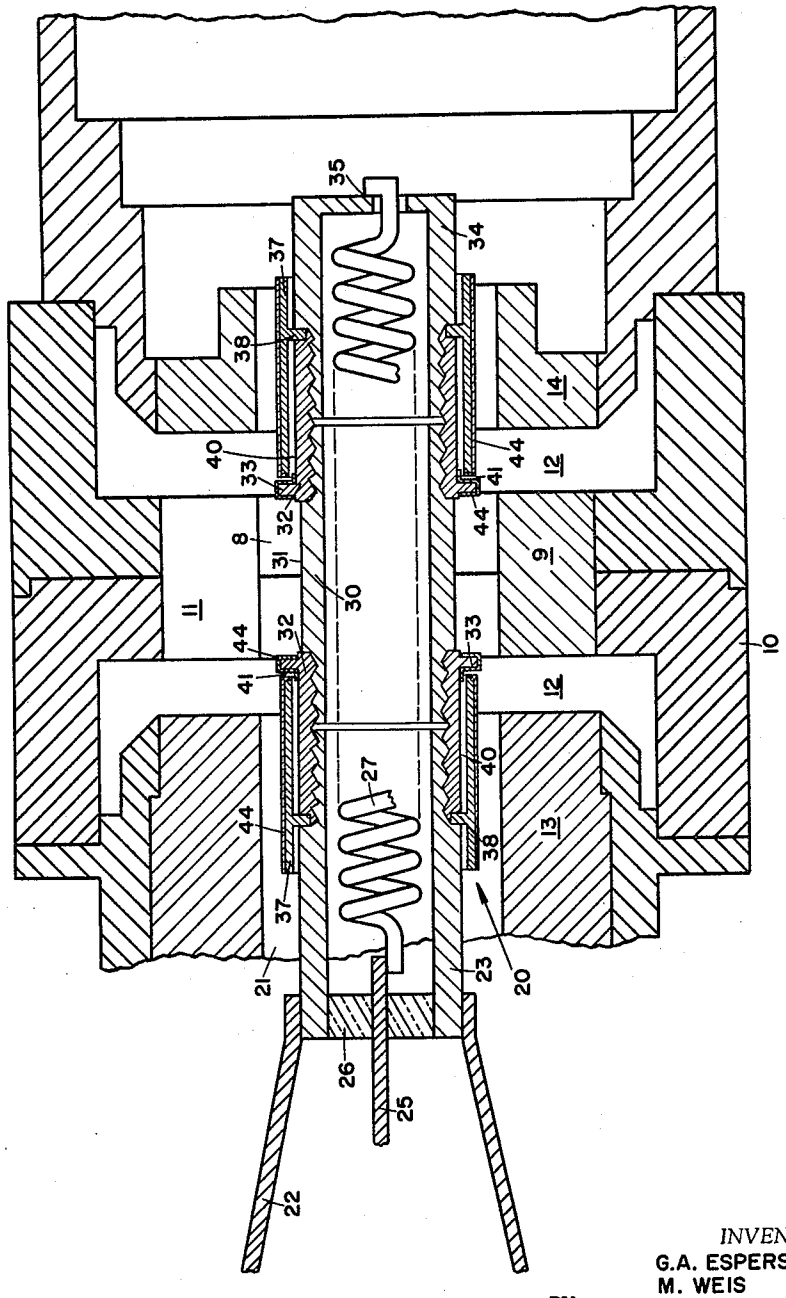
Oct. 18, 1960 G. A. ESPERSEN ET AL 2,957,100

MAGNETRON CATHODE STRUCTURE

Filed Aug. 27, 1957



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United States Patent Office 2,957,100 Patented Oct. 18, 1960

2,957,100

MAGNETRON CATHODE STRUCTURE

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Filed Aug. 27, 1957, Ser. No. 680,496

3 Claims. (Cl. 313—346)

Our invention relates to cathode structures for magnetrons and the like, and in particular to a dispenser-type cathode structure for magnetrons.

The usual cathode employed in a magnetron tube is the oxide type, which comprises a base structure supporting some form of alkaline earth oxide coating. While such cathodes have operated satisfactorily in magnetrons, there has always been present the disadvantage of a relatively short lifetime for such tubes, which in many cases has abruptly ended. This is believed due to a dislodgment of the oxide coating from the base, having the effect of changing the internal geometry of the electrodes and also of rendering parts of the cathode non-emissive. The recent availability of the dispenser-type cathode, it was hoped, would result in a magnetron whose life-time could be extended by at least a factor of five. Typical dispenser cathodes are described in United States Patents Nos. 2,543,728; 2,700,000; 2,700,118, and in a United States patent application, Serial No. 487,042, filed February 9, 1955. The significant difference between this cathode and the oxide type is the fact that, in the former, the emitting surface is a metal surface covered with a monolayer of an activating substance, such as barium. Thus, dislodgment of a thick coating due to arcing or severe back-bombardment within the tube cannot occur. A disruption of the activating monolayer is not serious as it is being continuously regenerated by chemical reactions within the cathode. However, there were thought to be two major drawbacks to the use of a dispenser-type cathode in a magnetron. First, it is well known that the total anode current in a magnetron is due for a smaller part to primary emission of the cathode, and for a much greater part to secondary emission from the cathode produced by back-bombardment of the cathode emitting surface by returning electrons and possibly some positive ions, which secondary emission is essential to produce the high current levels necessary to obtain satisfactory operation. It is also known that an oxide surface is a better secondary emitter than a metal surface. It was therefore thought that the low secondary electron emission yield of the metal emitting surface of a dispenser cathode would limit its applicability in many types of magnetrons. The second disadvantage was its relatively higher operating temperature than that of the ordinary oxide cathode. For example, the usual oxide cathode activates at about 850° C. and operates between 750 and 850° C. The average dispenser cathode activates at about 1100° C. and operates between 950 and 1100° C. This higher operating temperature of the dispenser cathode requires the use of different materials for the cathode support structure, and makes the heat dissipation problem more severe, as well as compelling the use of cathode elements that could function at these higher temperatures.

Despite these apparent shortcomings, we have produced an improved cathode structure with a dispenser-type emitting body for a magnetron tube which not only

exhibits the much longer lifetime one might expect from the substitution of the dispenser cathode for an oxide cathode, but, and this is entirely unexpected, also enables operation under conditions such that its operating temperature is actually lower than the operating temperature of an oxide cathode in an electrically-similar tube, indicating that the secondary electron emission yield of the dispenser-type cathode is far greater than that encountered with the oxide cathode. Another advantage of this cathode structure is improved performance of the magnetron as an oscillator, because oscillation is initiated at a lower value of anode current than that of a corresponding tube built with an oxide cathode, again a decidedly unexpected result of the construction of the invention.

Briefly, the results of the invention have been achieved by a cathode construction involving a dispenser-type emitting body provided with end shields for confining the electron emission in the active anode-cathode space, and magnetic, field-shaping members located at opposite ends of the emitting body for shaping the magnetic field at the cathode emitting surface to enhance its secondary emission. Preferably, both the end shields and the magnetic field-shaping members are covered with an emission-inhibiting material to suppress leakage emission from the end structures and thus improve the tube's operating efficiency.

The invention will now be described in greater detail with reference to the accompanying drawing, in which the sole figure is a cross-sectional view of the electrode structure of a magnetron employing one form of the improved cathode of the invention.

Referring now to the drawing, the electrode structure of the magnetron shown therein comprises an anode block **10** having inwardly-extending anode segments **9** defining a plurality of circularly-arranged, resonant cavities **11** surrounding a central space **8**. The anode segments **9** may be provided by brazing a plurality of radially-extending vanes to the inner surface of the anode block **10**, though it will be appreciated that other forms of segments producing other shapes of cavities are equally suitable. So, for example, the cavities might be of the hole and slot type, or a rising-sun construction may be used if desired. Straps interconnecting alternate anode segments may also be provided if desired. The cavities **11** are intercoupled by end spaces **12** at opposite sides thereof, which end spaces **12** are enclosed by end closures including internally-extending magnetic pole pieces **13** and **14**. To the opposite ends (not shown) of the iron pole pieces **13** and **14** is coupled a magnetic-field-producing element, such as a permanent magnet, so as to establish an axially-directed magnetic field in the central space **8** between the pole pieces **13** and **14**. The cavities in the right pole piece **14** are for receiving a tuner mechanism for tuning the magnetron. However, as it has nothing to do with the invention, the tuner has been omitted for the sake of clarity. A cylindrical cathode structure, indicated generally as **20**, extends axially through a bore **21** in the left pole piece **13** through the central space **8** concentrically with the cavities **11**. The support structure of the cathode **20** includes a conductive conical member **22** brazed to a hollow, molybdenum, support member **23**. The conical member **22** constitutes one terminal of a coaxial-type cathode input construction. The other terminal is constituted by a central rod **25**, which is supported by an alumina insulator **26** mounted in the molybdenum support **23**. To one end of the rod **25** is secured a heater element **27** of the helical type, which extends through the hollow, cylindrical-type cathode.

The emitting portion of the cathode **20** comprises a refractory metal body **30**, such as tungsten, impregnated

with an activating material in the form of an alkaline earth metal composition, which is preferably made as described in United States patent application, Serial No. 487,042, filed February 9, 1955, though the structures described in the United States patents enumerated above would also be satisfactory. For example, the impregnant of this porous tungsten member 30 may be a fused mixture of barium carbonate, aluminum oxide, and calcium carbonate in a 5:2:3 mole ratio. The emitting surface of the cathode, which is a right circular cylinder designated by reference numeral 31, is located concentrically within the anode block 10. The ends of the impregnated tungsten member 30 are threaded, and engaging those threads are a pair of molybdenum cylinders 32 with enlarged end portions 33 serving as end shields. That is, the end shields, which are at cathode potential, establish an inclined electrostatic field to the anode which tends to confine electron emission from the cathode to the active anode-cathode space 8 and out of the end spaces 12. While molybdenum is preferred for the end shield members 32, other refractory metals, such as tantalum, may also be used. As will be noted, the end shield members 32 each threadingly engage one end of the impregnated tungsten member 30 and an adjacent end of the molybdenum support 23 and a heat dissipator 34, preferably also of molybdenum, respectively. These five, hollow, threaded members thus constitute a solid, integral structure, all conductively connected together and thus at the same cathode potential. As is the usual practice, one end of the heater 27 is connected at 35 to this integral cathode body. Of course, it will be appreciated that other means may be employed to join the cathode elements together to form an integral body.

A pair of field-shaping members 37 are secured to opposite ends of the cathode body. These field-shaping members 37, which are constituted of a high permeability magnetic material, such as that known under the trade name "Permendur," comprise cylindrically-shaped hollow members each with three (two of which are shown for clarity's sake), internally-projecting, circumferentially-spaced portions 38, which are seated in spaces provided between the molybdenum support 23 and left end shield member 32, and the molybdenum dissipator 34 and the right end shield member 32, respectively, and locked in that position by the threaded end shield members 32. The only connection between each of the field-shaping members 37 and the cathode body proper are these three small projections, which are like point contacts, so that the heat conduction between the field-shaping members and the cathode body is minimized. This mounting of the field-shaping members 37 establishes an annular slot 40 between the field-shaping members and the cathode body, which slot serves as a heat barrier, as well as gaps 41 between the ends of the field-shaping members 37 and the enlarged portions 33. By maintaining only point contact connections between the cathode body and the field-shaping members 37, and by the provision of the spacings described, it is ensured that the temperature of the field-shaping members 37 is maintained considerably below that of the cathode body itself. While three point contacts have been described, the number employed is not critical. In fact, extension of the points to form an annular ring and thus a line contact may also be satisfactory depending on the final operating temperatures of the several cathode elements. In general, then, the contact should be one of small area to minimize as much as possible the heat conduction to the field-shaping members. The construction shown also provides that the internal diameter of the field-shaping members 37 is greater than the outside diameter of the cathode emitting surface 31. As will also be noted, the outer diameter of the enlarged portions 33 of the end shields is greater than the outside diameter of the field-shaping members 37. Both the molybdenum end shield members 32 and the magnetic field-shaping members 37 are provided with an outer coating 44 of an emission-inhibiting material to suppress leakage emission from these end structures. The emission-inhibiting material preferred is zirconium metal, which may be applied by painting the desired surfaces with a powder-liquid suspension of zirconium hydride powder in an amyl-acetate vehicle, and then sintering at about 1100° C. in vacuum to cause tight adherence of the resultant zirconium layer to the substratum. The resultant surface is fairly smooth and uniform and can be made within required tolerances. The actual zirconium coating 44 used is extremely thin, of the order of 250 microns. However, thicker coatings have also been used with equally satisfactory results. As shown, the emission-inhibiting coating 44 extends over all of the surfaces of the field-shaping members and end shields that are exposed to electron bombardment or to receiving evaporated activating material (barium) from the impregnated tungsten cathode.

In operation, after the tube has been assembled, properly degassed, and sealed off, the cathode may be activated by heating for a short time at 1100° C. Then, a suitable pulsed voltage is applied between the anode and cathode to cause the tube to oscillate, and the heater voltage adjusted until the desired anode current is obtained. One of the truly remarkable features of the cathode construction of the invention is that, for the desired operation, it was found that the heater voltage necessary produced a cathode temperature of the order of 850° C. This is extremely low as an operating temperature for a dispenser cathode of the type described. As a matter of fact, it indicates that most, if not almost all, of the electron emission is secondary electron emission, despite the fact that the emitting surface 31 of the cathode is metallic in nature rather than oxidic. This unusual result has been attributed to the shaping of the magnetic field in the vicinity of the cathode so as to cause the returning electrons to strike the emitting surface 31 at angles at which high secondary electron emission yields are possible. The required low operating temperature of the cathode has the advantage of a much lower evaporation rate of activating material and thus less of a problem of spurious emission from undesired, non-emitting cathode portions. To further ensure the latter result, the emission-inhibiting coating 44 is provided. This guarantees that, during the operating or starting cycle, low primary emission from the field-shaping members and the end shields obtains. The magnetic field in the active anode-cathode space is produced by, as is conventional in the art, a permanent magnet (not shown) coupled to the ends of the two pole pieces 13 and 14 and serving to provide a high flux density in said active space 8. The field-shaping members 37, being magnetic, help to establish a more intense field at the cathode emitting surface 31 and thus contribute to the high secondary electron emission yield found with the construction of the invention.

It is also noted that the Curie point of, for example, the magnetic material Permendur, whose composition is 49% Co, 2% V, balance Fe, is about 930° C. This is the temperature at which the permeability of the material is reduced to that of air. It will be obvious therefore that such materials cannot function as constituents of field-shaping members at the Curie temperature or higher. This has been one of the reasons why it was not thought possible to combine dispenser-type cathodes, which usually operate at 1050° C., with Permendur field-shaping members. The obtainment of this result from the construction of the invention, due to the improved field-shaping at the cathode resulting in a higher secondary emission yield and thus a lower operating temperature of the cathode, is considered one of the key features ensuring success of the cathode in this application. The permeability characteristic of a magnetic material is a reversible one, so that the fact that the field-shaping members may be exposed to a higher temperature than

their Curie point during activation of the dispenser-type cathode is not significant.

While the construction of the invention has been described in combination with the use of zirconium as an emission-inhibiting material, it is to be noted that, while zirconium is preferred, other emission-inhibiting materials may also be used. For example, if the temperature is low enough, titanium may be satisfactory. Further, a carbon coating would also tend to reduce primary emission. It will also be evident that the end shield members **32** may be constituted entirely of zirconium, rather than zirconium-coated molybdenum. It is also considered that the same results are obtainable with other dispenser cathodes having metallic emitting surfaces.

To illustrate more specifically one satisfactory structure of the invention, though this is not to be considered as in any way limiting the invention, the diameter of the cathode emitting surface **31** was 19/64 inch; the inside diameter of the inwardly-extending pole pieces was 29/64 inch (the outside diameter is not significant); the outside diameter of the field-shaping members **37** was about 3/8 inch, and its internal diameter about 5/16 inch; the outside diameter of the enlarged end shield portions **33** about 25/64 inch; the slot width **40** was about 0.007 inch; the gap width **41** was about 0.020 inch; the actual length of the cathode emitting area was about 5/16 inch; and the pole piece spacing was about ½ inch.

While we have described our invention in connection with specific embodiments and applications, other modifications thereof will be readily apparent to those skilled in this art wtihout departing from the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. A cathode construction comprising a cylindrical body having a central axis and constituted of a tungsten member impregnated with an alkaline earth metal composition, a pair of metal end-shield members mounted on and at opposite ends of said cylindrical body and each having a radially-extending portion of larger outside diameter than that of the impregnated tungsten member for confining the electron flow in desired areas, and a pair of magnetic field-shaping members mounted on and at opposite ends of the cylindrical body but beyond the end shield members, said field-shaping members being constituted of a magnetic material containing approximately equal proportions of cobalt and iron and each comprising a hollow, elongated, cylindrical member coaxial with and joined to said cylindrical body by internally-projecting portions of small surface area to minimize heat conduction thereto, said field-shaping members each being otherwise spaced from the cylindrical body and adjacent end-shield member by small annular gaps and having an inside diameter slightly greater than the outside diameter of the impregnated tungsten member and an outside diameter slightly smaller than the outside diameter of the adjacent-end shield member, and means for heating the cylindrical body.

2. A cathode construction as set forth in claim 1 wherein a surface layer of primary-emission-inhibiting material is provided on the outer exposed surfaces of the end-shields and field-shaping members.

3. A magnetron comprising cavity resonators surrounding a central space, internally-extending, hollow pole pieces at opposite ends of the central space, and in the central space and extending within the hollow pole pieces a cathode construction comprising a cylindrical body having a central axis and constituted of a tungsten member impregnated with an alkaline earth metal composition, a pair of metal end-shield members mounted on and at opposite ends of said cylindrical body and each having a radially-extending portion of larger outside diameter than that of the impregnated tungsten member for confining the electron flow in desired areas, a pair of magnetic field-shaping members mounted on and at opposite ends of the cylindrical body but beyond the end-shield members, said field-shaping members being constituted of a magnetic material containing approximately equal proportions of cobalt and iron and each comprising a hollow, elongated, cylindrical member coaxial with the cathode and extending within but spaced from the adjacent pole piece and closely surrounding and joined to said cylindrical body by small surface area connections to minimize heat conduction thereto, said field-shaping members each being otherwise spaced from the cylindrical body and adjacent end-shield member by small annular gaps and having an inside diameter slightly greater than the outside diameter of the impregnated tungsten member and an outside diameter slightly smaller than that of the end-shield member, a heater within the cylindrical body, and a surface layer of zirconium on the external surfaces exposed to the central space of the field-shaping members and end-shield members.

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