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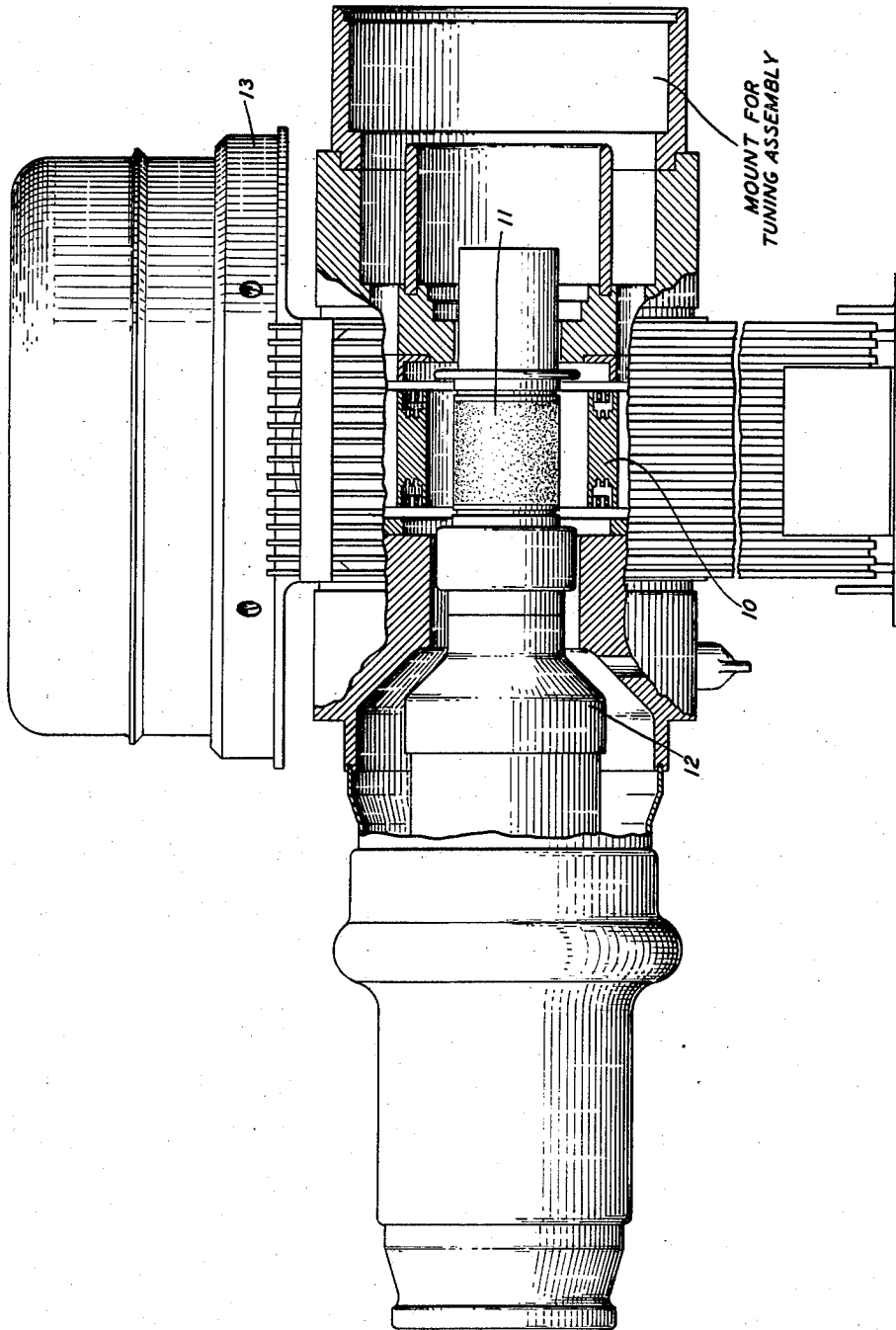
2,858,470

CATHODE FOR ELECTRON DISCHARGE DEVICES

Filed Feb. 2, 1955

2 Sheets-Sheet 1

FIG. 1



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FIG. 2

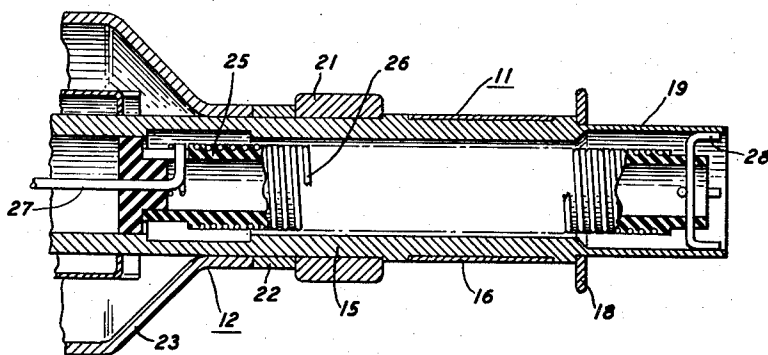
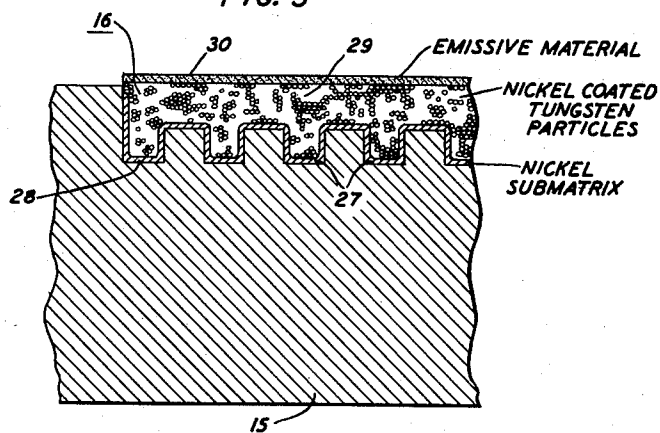


FIG. 3



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CATHODE FOR ELECTRON DISCHARGE DEVICES

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10 Claims. (Cl. 313—346)

This invention relates to cathode structures for electron discharge devices and more particularly to such cathodes supplying copious emission of electrons in high power transmitting devices, especially suitable for use in ultra high frequency systems such as magnetrons, and to methods of fabricating such cathodes.

In magnetrons, very severe requirements are imposed upon the cathode structures. Some typical specified characteristics of a magnetron cathode include

- (1) Adequate stable primary emission,
- (2) High secondary emission ratio,
- (3) Resistance to thermionic poisoning,
- (4) Good adherence and coherence of emissive coating,
- (5) Rapid degassing, activation and ageing-in,
- (6) High thermal and electrical conductivity,
- (7) Resistance to fusion, sublimation and sputtering,
- (8) Freedom from sparking and arcing, especially on long pulse duty cycles,
- (9) Resistance to high speed ion or electron bombardment,
- (10) Reproducibility, dependable performance, and long life,
- (11) Very large pulsed current emission.

Initially it was found that magnetrons could utilize conventional oxide coated cathodes, the oxide coating being placed directly on a nickel cylinder which had only to be slightly roughened as by etching, blasting or sintering thereon a thin sprayed or painted coating of nickel powder. As the frequency and power ratings of magnetrons increased, it was found that these cathodes were unsatisfactory. In magnetrons very high current densities, as of the order of 50 amperes per square centimeter, may be required. In order to attain such current densities, it was next proposed to employ what has been referred to as a "mesh" type cathode in which a woven nickel mesh is placed onto a nickel or molybdenum cylinder and the electron emissive material packed into the interstices of this mesh. While this cathode is satisfactory for certain purposes and certain types of tubes, it was found that the resistance of the cathode coating might be reduced and the performance of the cathode improved if the nickel were distributed more evenly throughout the coating. Accordingly it was then proposed to replace the nickel mesh with a sintered matrix of coarse nickel powder. The active material is packed into this matrix in much the same manner as the mesh cathode. Such cathodes have become known as "matrix" cathodes. These magnetron cathodes are discussed in the article "The Magnetron as a Generator of Centimeter Waves," by J. B. Fisk, H. D. Hagstrum, and P. L. Hartman, Bell System Technical Journal, vol. 25, page 167 (April 1946), and particularly at sections 10.7 and 21 thereof; additionally, one particular matrix cathode is described in L. M. Field Patent 2,594,897, April 29, 1952.

In order to improve the matrix cathode structure, it was then suggested that the matrix and the emissive material be applied to a molybdenum core. In such case it

was found necessary to interpose a nickel submatrix applied and sintered under suitable conditions to protect the base metal against oxidation by carbon dioxide during breakdown of the active coating and to facilitate bonding of the coarse nickel matrix to the molybdenum core.

However, it has been found that when the cathode structure is increased in size, as to having a one inch diameter molybdenum core such as is desired for a one megawatt magnetron, a serious problem arises due to the differential expansions of the molybdenum core and the nickel matrix. The expansion coefficient of the molybdenum cylinder is only about one-third that of a nickel matrix and for these large cathode structures it has been found that there is an inevitable rupturing of the bond between the two metals with a concomitant disintegration of the matrix. This is particularly true under certain operating conditions of the magnetrons involving thermal cycling.

Matrix type cathodes using other materials than nickel are also known in the art, such as that known as the L cathode described in an article "A New Thermionic Cathode for Heavy Loads," by H. J. Lemmens, A. J. Jensen, and R. Loosjes, Philips Technical Review, vol. 11, page 341 (June 1950), wherein a tungsten powder is compressed onto a molybdenum core to form the matrix of the cathode. Considerable difficulty is encountered, however, in obtaining sintering of tungsten powder at reasonable temperatures. To overcome this difficulty various expedients are utilized, such as compressing the tungsten matrix under high pressure. Another known technique is to obtain a temporarily copper-bonded machinable tungsten matrix; the infused copper is later removed by vacuum firing to give a pure porous tungsten matrix. However, a pure tungsten matrix is also subject to differential thermal expansions on a large molybdenum core.

It is an object of this invention to provide an improved cathode structure for electron discharge devices and particularly such a structure for high power ultra high frequency devices, such as magnetrons.

It is a further object of this invention to provide a large cathode structure which may be utilized in very high power magnetrons.

A further object of this invention is to obtain a cathode structure wherein the adherence of the matrix to the core is not subject to rupturing during heating or thermal cycling of the cathode.

It is a still further object of this invention to provide an improved method for fabricating a matrix type magnetron cathode structure.

Another object of this invention is to provide a matrix type cathode incorporating tungsten that has the advantages of a tungsten cathode matrix without the disadvantages of such matrices.

It is still another object of this invention to enable the attainment of a cathode matrix incorporating tungsten without the employment of high temperature or high pressure techniques in the processing of the matrix.

These and other objects of this invention are attained in one specific embodiment wherein the matrix is coexpansive with the cathode core. Specifically, according to my invention, the matrix comprises a coarse tungsten powder coated with nickel, the linear tungsten to nickel ratio in the matrix being about four to one, thereby matching closely the expansivity of the molybdenum. The nickel-tungsten matrix is impregnated with an electron emissive coating in the same manner as prior matrix cathodes.

In accordance with an aspect of this invention, the surface of the coarse tungsten powder, which may be of 200 to 400 mesh, is moistened as with a plasticized nitrocellulose solution. While the surface is still tacky, an impalpably fine powder of nickel, nickel oxide, or a com-

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bination of both nickel and nickel oxide is coated onto the outer surface of each of the tungsten particles. This may advantageously be done, in accordance with this invention, by dusting the nickel or nickel oxide powder onto the tungsten particles while they are being continuously agitated to insure uniform random coverage. The coated powder, when dry, is hydrogen reduced, after which it can be processed in the same manner as a pure nickel powder.

Specifically, in one illustrative embodiment of this invention, a molybdenum cathode blank has been prepared by forming a spiral groove on its outer surface and positioning a nickel submatrix on the molybdenum blank at this grooved portion. The submatrix may advantageously be formed by painting a suspension of fine nickel powder bonded with a nitrocellulose solution onto the cathode blank. The nickel powder is then advantageously fused at the eutectic temperature of the molybdenum and nickel to form an interdiffused alloy between the nickel submatrix and the molybdenum base. A subsequent coating of the fine nickel powder is then applied. While this coating is still wet, a thin deposit of a coarse nickel powder is sprinkled onto it and the subsequent coating of the fine nickel powder and the deposit of coarse nickel powder are permanently bonded into the nickel submatrix by another hydrogen sintering treatment.

The molybdenum cathode blanks with the submatrix thus placed on them are positioned in molds of oxidized stainless steel and the cathodes filled with the tungsten-nickel powder prepared as described above; the blanks are then fired in hydrogen at a temperature from 900 to 1000 degrees centigrade. The cathodes are then removed from the mold and the matrix resintered from 1200 to 1300 degrees centigrade. Cathode extensions may then be brazed onto the core structure and the matrix impregnated with a barium-strontium carbonate suspension and the cathode structure then compressed to its desired size. Assembly, pumping, and activation may then occur in the usual manner for matrix type cathodes.

In accordance with another aspect of this invention, the nickel in the submatrix and the nickel coated onto the outer surface of the tungsten particles are related to the amount of tungsten in the cathode matrix by a linear relationship of four to one. By linear relationship, it is meant that from the surface of the molybdenum cathode along a radial line extending through the nickel and tungsten matrix and submatrix to the outer surface of the cathode, the amount of tungsten will be four times greater than the amount of nickel. By providing for this novel relationship, a coexpansive system is provided whereby the expansivity of the coating on the molybdenum core substantially matches the expansivity of the molybdenum itself. It should be pointed out that because expansions depend on length or linear dimensions rather than weight or volumetric relationships, the relation between the tungsten and nickel, whereby the ratio of tungsten and nickel is four to one, is a linear or length relationship and is not a relationship by weight, which would be nearer to two to one.

It is a feature of this invention that a cathode comprise a metallic core on which is placed a matrix comprising nickel-coated tungsten particles in which is interspersed an electron emissive material.

It is a further feature of this invention that a cathode comprise a molybdenum core on the outer surface of which is secured a matrix of nickel-coated tungsten particles in which is interspersed an electron emissive material. More specifically, in accordance with a feature of this invention, the linear ratio of tungsten to nickel on the core is substantially four to one whereby the core and the matrix are substantially coexpansive.

It is a still further feature of this invention that a nickel submatrix be interposed on the molybdenum core between the core and the matrix of nickel-coated tungsten particles. More specifically in accordance with this

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feature of the invention, the desired ratio of tungsten to nickel on the core is determined by both the nickel in the submatrix and the nickel coated onto the tungsten particles.

It is another feature of this invention that the nickel submatrix form an alloy of nickel and molybdenum with the cathode core and an alloy of nickel and tungsten with the cathode matrix.

It is another feature of this invention that a cathode be fabricated by applying a binder solution to tungsten particles, placing a very fine nickel powder, nickel oxide powder, or combination of the two, on the tungsten particles while the solution is still tacky, reducing and sintering the coating, and then applying the coated particles to a cathode core.

It is still another feature of this invention that the fine nickel and/or nickel oxide powder be dusted onto the tungsten particles while the particles are being continuously agitated to assure a uniform coverage of the entire surface of all of the tungsten particles.

A complete understanding of these and various other features of this invention may be gained from consideration of the following detailed description and the accompanying drawing in which:

Fig. 1 is a side view, partially in section, of a magnetron incorporating a cathode structure in accordance with this invention;

Fig. 2 is an enlarged sectional view of the cathode structure of the embodiment of Fig. 1; and

Fig. 3 is a sectional view of a portion of the cathode, the cathode matrix being shown enlarged for purposes of explanation of the invention.

Turning now to the drawing, Fig. 1 is a side view, partially in section, of a magnetron incorporating a cathode in accordance with this invention. As there seen, the magnetron, which may be of any of the types well known in the art, includes a slotted anode 10 in a central aperture of which is positioned the cathode 11 attached to a cathode assembly 12; a tuning assembly, such as is shown in J. W. West Patent 2,657,334, October 27, 1953, is mounted in the end cap and includes tuning pins extending into the anode bores. An output assembly 13 is electromagnetically coupled to one of the slots or bores of the anode 10.

The portion of the cathode assembly 12 pertinent to the present invention, as best seen in Fig. 2, comprises a cylindrical core or base member 15, which may advantageously be of molybdenum, and on which is placed the cathode matrix 16. A cylindrical flange 18 is adjacent to one end of the matrix 16 and serves as an electrostatic shield; the end portion 19 of the cathode core 15 advantageously extends into the adjacent pole piece and serves as a heat radiator. Adjacent to the other end of the cathode matrix 16 is a wider flat flange member 21 which serves as an inner pole piece member. A spacer 22 is between the flange member 21 and a cone-shaped support member 23 which is attached to the coaxial input support of the cathode assembly.

Positioned within the cathode is the heater assembly which may advantageously comprise a hollow insulating core 25 on which a heater wire 26 is helically wound. One end of the heater wire is connected, as by a lead 27, to the inner element of the coaxial support, and the other end of the heater wire is connected, as by a spacer member 28, to the cathode core 15 which, as noted above, is connected by the cone-shaped member 23 to the outer element of the coaxial support.

Referring now to Fig. 3, there is shown greatly enlarged a cross section of a portion of the molybdenum core 15 with the coating thereon after the electron emissive material has been placed on the surface of the tungsten-nickel matrix but before the electron emissive material has been absorbed into the matrix. As there seen, the molybdenum core advantageously has spiraled grooves 27 into which the nickel submatrix 28 is advan-

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tageously placed. These grooves may be employed to afford a stronger bond between the cathode matrix and the cathode core. However, I have found that in a co-expansive system in accordance with my invention wherein the cathode matrix comprises nickel-coated tungsten particles as described above, the spiral grooves are not necessary and may be omitted without weakening the bond between the cathode core and the matrix and without increasing the possibility of rupturing of the matrix from the cathode core. The nickel-coated tungsten particles 29 are positioned on top of the nickel submatrix. Actually, just as there exists between the nickel submatrix and the molybdenum core an interfused alloy of nickel and molybdenum, I have found that there is likewise between the nickel submatrix and the nickel-coated tungsten matrix an interfused alloy of nickel and tungsten. These transition layers contribute to the expansivity of the system, supplementing the effect of the nickel coating on the tungsten particles. I have therefore found it advantageous to employ a nickel submatrix. However, it is to be understood that, if desired, the total amount of nickel requisite to attain a coexpansive system, that is a system in which the linear relationship between the amount of tungsten and nickel is in a ratio of four to one, may be attained solely by the coating of the nickel on the outer surface of the tungsten particles. This would increase the amount of nickel requisite to attain this linear relationship and would also require that the nickel be coated onto the tungsten particles in several steps as it is not advantageous to put a large amount of nickel onto the tungsten particles in one application.

The electron emissive material 30 is placed onto the outer surface of the nickel-coated tungsten matrix in a very fine suspension, as seen in Fig. 3. The emissive material does not, however, remain on the outer surface of the cathode matrix but instead soaks into the pores of the matrix so that the matrix becomes impregnated with the emissive coating. The matrix is then compressed to increase the density of the matrix, thereby improving its conductivity and electrical and mechanical properties. Any suitable highly active electron emissive material may be incorporated in the cathode coating 16; advantageously this emissive material may include alkaline earth oxides, such as those of barium, strontium, and calcium. The matrix itself is relatively thick and was applied to the core 15 and the submatrix 28 as a spongy semi-porous coating which was heated, as discussed below, to produce coalescence in the matrix and positive bonding of the matrix to the submatrix 28 and thus to the core 15.

Accordingly, in this embodiment of this invention, the cathode comprises a core on which is placed a nickel submatrix, a cathode matrix composed of nickel-coated tungsten particles, and a heater element within the core to heat the cathode structure. Although the cathode core may be of fairly large outer diameter, such as of the order of one inch or more, the matrix will not tend to crack or break away from the core due to thermal stresses as the matrix and the core are coexpansive. Specifically, in accordance with one specific embodiment of the invention, wherein the core is of molybdenum, which has a relatively low coefficient of expansion, the matrix comprises nickel-coated tungsten particles in which the linear tungsten to nickel ratio between the core 15 and the surface of the matrix is four to one.

The cathode matrix is advantageously fabricated, in accordance with another aspect of this invention, by moistening the surface of the coarse tungsten powder with a suitable binder solution, such as a plasticized nitrocellulose solution. The tungsten particles may be of the order of 200 to 400 mesh. While the surface is still tacky a very fine nickel powder, nickel oxide powder, or powder of both nickel and nickel oxide, is dusted onto the particles; during the dusting operation the tungsten particles should be agitated to insure uniformly random coverage. This dusting may be attained by shaking

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or blowing the oxide powder onto the agitated tungsten particles.

I have found it advantageous to coat the nickel or nickel oxide powder onto the tungsten particles by a dusting process, as described above. However, it is to be understood that the tungsten particles might also be coated by an electroplating or vapor deposition technique.

When the binder has dried with the very fine nickel and/or nickel oxide powder on the surface of the particles, the particles are placed in a furnace where they are hydrogen reduced and sintered, as at a temperature of 600 to 900 degrees centigrade. The further processing of the cathode can then proceed in the manner known in the art for pure nickel matrices. In one such process, that may be employed, the molybdenum cathode cores, having priorly had nickel submatrices coated thereon, are placed in molds of stainless steel, the molds filled with the prepared powder, and the cathodes fired in hydrogen at 1000 degrees centigrade. The cathodes are then removed from the molds and the matrix again sintered at 1250 degrees to 1300 degrees centigrade firmly to bind the matrix coating to the core.

The electrostatic shield 18 and other members, described above, are then brazed onto the cathode core 15 after which the matrix is impregnated with an emissive coating, such as barium strontium carbonate suspension, and finally compressed to the specified size. The cathode is assembled in the magnetron, which is evacuated; the cathode is then activated by breaking down the carbonates to the oxides after which it is aged.

Cathode matrices prepared and having the structure described above and in accordance with this invention have the excellent electrical characteristics of the prior known all nickel matrix cathodes, but at the same time the excellent mechanical properties of the cathode are those of tungsten. Thus I have found that the initial stabilization time, the arm-rate on long pulse operation, the resistance to cracking on thermal cycling, and the life are all substantially improved over prior pure nickel matrix cathodes. Hence in this uniquely rugged coexpansive refractory system defining a matrix cathode are combined the best features of each component, whereby the cathode can satisfy the exacting criteria of performance and life requisite for many magnetrons.

It is to be understood that the above described arrangements are illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A cathode structure comprising a metallic core, a sintered matrix secured to the outer surface of said core, said matrix comprising a plurality of tungsten particles, each completely coated with nickel, and a heater element for heating said core and matrix.

2. A cathode structure comprising a metallic core, a sintered matrix secured to the outer surface of said core and comprising a plurality of nickel-coated tungsten particles and electron emissive material interspersed with said particles, and a heater element thermally associated with said core for heating said core and said matrix.

3. A cathode structure in accordance with claim 2 wherein said core is of molybdenum and the linear ratio of tungsten to nickel in said matrix is substantially four to one, whereby said matrix and said core are substantially coexpansive.

4. A cathode structure comprising a metallic core, a nickel submatrix bonded to said core, a cathode matrix bonded to said submatrix, said cathode matrix comprising nickel-coated tungsten particles, and a heater element for heating said core and said matrix.

5. A cathode structure comprising a molybdenum core, a nickel submatrix bonded to said core and forming a nickel-molybdenum alloy therewith, a cathode matrix bonded to said submatrix and comprising nickel-coated

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tungsten particles, electron emissive material interspersed in said matrix, and a heater element for heating said core and said matrix.

6. A cathode structure in accordance with claim 5 wherein the linear ratio of tungsten to nickel coated on said molybdenum core is substantially four to one whereby said matrix, submatrix, and said core define a substantially coexpansive system.

7. A cathode structure in accordance with claim 6 wherein said matrix and said submatrix define a nickel-tungsten alloy at the boundary between said matrix and said submatrix.

8. A cathode structure for incorporation in magnetrons comprising a hollow molybdenum sleeve, a sintered coating secured to the outer surface of said sleeve, said coating comprising a nickel submatrix and a matrix of nickel-coated tungsten particles and alkaline earth oxides interspersed with said particles, and a heater element within said sleeve for heating said sleeve and said matrix.

9. A cathode structure in accordance with claim 8 wherein said alkaline earth oxides comprise barium and strontium oxides.

10. A cathode structure for incorporation in mag-

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netrons comprising a hollow molybdenum sleeve, a sintered coating secured to the outer surface of said sleeve, said coating comprising a nickel submatrix and a matrix of nickel-coated tungsten particles and barium and strontium oxides interspersed with said particles, the linear amount of tungsten on said sleeve being substantially four times the linear amount of nickel on said sleeve whereby said coating and said sleeve are substantially coexpansive, and a heater element within said sleeve for heating said sleeve and said coating.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,858,470

October 28, 1958

Elmer A. Thurber

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 6, line 37, for "arm-rate" read -- arc-rate --.

Signed and sealed this 3rd day of March 1959.

(SEAL)
Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents