May 17, 1966 J. W. GAYLORD 3,251,641

ELECTRON TUBE AND METHOD OF MAKING THE SAME

Filed March 27, 1962

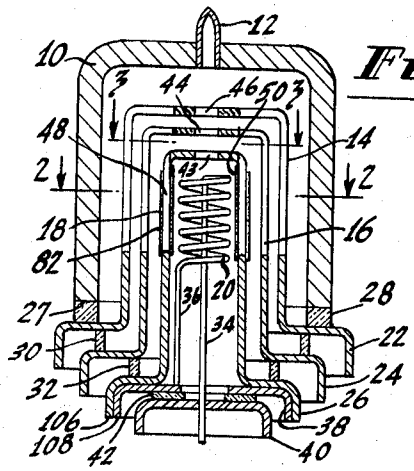


Fig. 1.

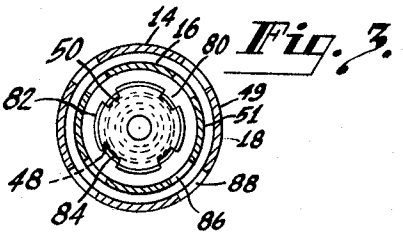


Fig. 3.

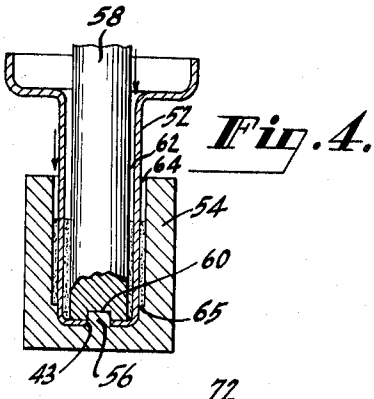


Fig. 4.

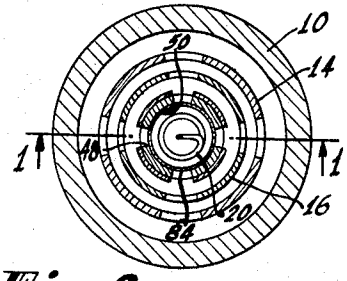


Fig. 2.

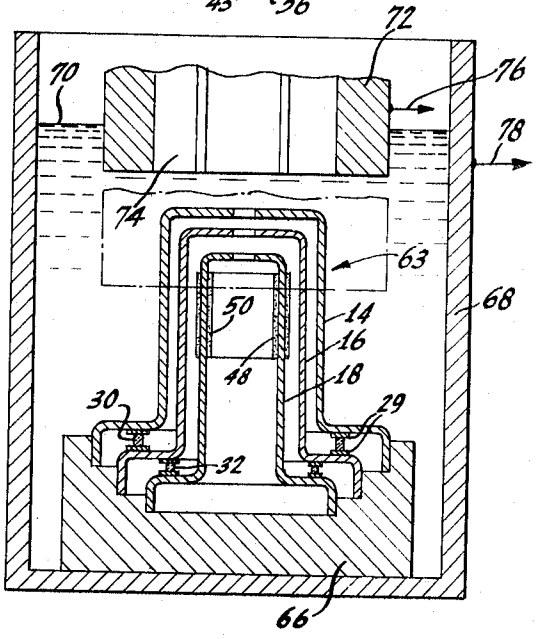


Fig. 5.

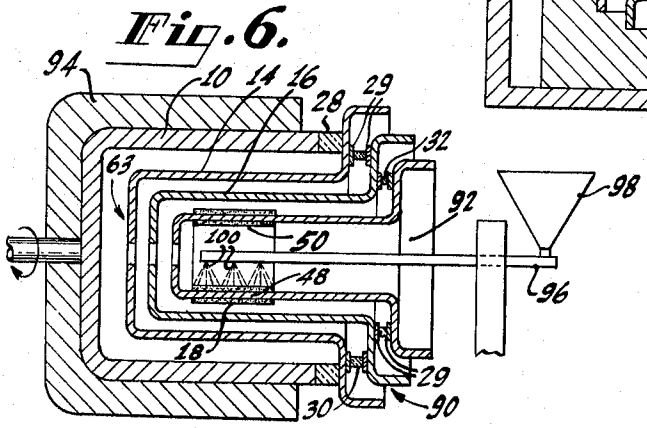


Fig. 6.

INVENTOR.
JOHN W. GAYLORD
BY
L. A. Larsen
ATTORNEY

United States Patent Office

3,251,641

Patented May 17, 1966

3,251,641

ELECTRON TUBE AND METHOD OF MAKING THE SAME

John Wallen Gaylord, Lancaster, Pa., assignor to Radio Corporation of America, a corporation of Delaware

Filed Mar. 27, 1962, Ser. No. 182,908
5 Claims. (Cl. 316—19)

My invention relates to electron tubes, and particularly to an improved tube having a tubular cathode and at least one tubular grid, and to a novel and advantageous method of fabricating such tube.

One type of electron tube of appreciably high power output comprises a tubular cathode including a non-foraminous metal base having on the outer surface thereof a coating of electron emitting material. Surrounding the cathode and coaxial therewith are two concentric tubular grids having radially registering slots. The slots may be produced by electrically eroding axially parallel elongated portions of imperforate grid blanks, after the blanks have been fixed mutually to provide a grid subassembly. One way in which the electrical erosion may be effected is described in U.S. Patent 2,980,984 to M. B. Shrader et al., issued April 25, 1961.

In tubes of the type referred to, some of the electrodes thereof are fixed in desired positions in a mount structure, by interposing a suitably metalized ceramic ring between adjacent flanges on which the electrodes are mounted, a suitable fixing material, such as BT solder being disposed between meeting surfaces of the flanges and ring. BT solder is an alloy consisting by weight of 28% copper and 72% silver. The electrode mount thus loosely assembled, is placed in an oven which is raised to a temperature high enough to melt the solder into intimate engagement with the coated ceramic ring and flanges. After the solder cools, it serves to fix the aforementioned parts with respect to each other.

While the fixing technique referred to, may be used for sealings parts that are free from harm by such technique, its use has not been feasible heretofore, for mounting the cathode and its associated heater. As concerns the cathode, this is for the reason that the cathode has thereon an emitting coating, usually in the carbonate form, prior to incorporation of the cathode in the tube structure. The reason for applying the coating before mounting the cathode, is that the cathode was inaccessible for application of the coating after it had been mounted in a tube. Such coating would be harmed if subjected to oven heat. In view of this situation, the cathode was affixed to the tube mount after the grids and anode had been mounted, by the application of localized heat, such as that involved in heliarc welding. The heater was not mounted in the tube prior to the mounting of the cathode, and therefore was the final element added to the tube structure.

However, while locally applied heat for fixing the cathode and heater in a tube mount has been tolerated heretofore because of necessity, it is not as good for tube quality as heat applied to the parts uniformly, as in an oven. One important advantage of oven type heating is that it reduces the likelihood of unrelieved strains in the tube structure.

It is an important object of the invention to provide an improved electron tube structure.

Another object is to provide an improved method of making an electron tube, in which the cathode is fixed in a tube mount by means of oven heating.

A further object is to provide a novel electron tube subassembly comprising a cathode and at least one grid.

Another object is to provide a novel cathode and method of making the same.

One structural example of the invention is an electron tube having a grooved metal cathode sleeve coated with a

metal matrix such as sintered particles of nickel. The matrix extends inwardly of the cathode sleeve to provide a circumferentially continuous inner surface having emitting material in the pores of the matrix. The grooves in the cathode sleeve leave circumferentially-spaced regions elongated axially, that is, parallel to the sleeve axis. These regions are occupied solely by a thin matrix and the matrix in that region is recessed inwardly from the immediately adjacent, outwardly exposed cathode surface. The thin, recessed regions referred to, comprise substantially the sole emitting portions of the cathode, and are in accurate radial register with slots in one or more adjacent grids. The resultant structure possesses good beam forming properties and is characterized by increased ruggedness and long life.

An advantageous method of making the tube structure referred to involves mounting and mutually fixing all components of the tube except the cathode heater, to provide a sub-assembly wherein the inner surface of the mounted cathode is accessible through an end opening thereof for the application thereto of a coating of emitting material. After application of the coating, a heater mount is extended into the cathode through the opening referred to and sealed thereacross.

A feature of the invention involves effecting all seals in the tube structure by oven heating, except the seal involving the heater mount, for uniformity in the several seals and avoidance of objectionable strains in the seal regions. This is particularly significant in connection with the cathode, in that this method assures cleanliness of this electrode by avoiding handling thereof after heating.

A further feature of the method comprises eroding selected regions of the cathode and one or more grids, after these electrodes have been fixed to each other, to provide radially registering eroded regions in the electrodes mentioned.

Another features involves making a cathode of the tubular type by slitting a tubular blank, coating the inner surface of the slitted portion of the blank with metal particles, and sintering the particles.

Further objects and features of the invention will become apparent as the present description continues.

Referring now to the drawing for a more detailed consideration of an exemplary embodiment of the invention,

FIG. 1 shows an elevation in section, of an electron tube using my invention;

FIG. 2 is a view in cross-section taken along the lines 2—2 of FIG. 1;

FIG. 3 is a cross-sectional view taken along the lines 3—3 of FIG. 1, and shows the top of the cathode;

FIG. 4 is a sectional view in elevation of apparatus employed in carrying out one of the steps of making the cathode;

FIG. 5 is a sectional elevation of a cathode-grid subassembly in operative relation with respect to apparatus for eroding radially registering areas therein; and

FIG. 6 is a longitudinal sectional view of an anode-grid-cathode sub-assembly associated with apparatus for applying an emitting coating to the inner surface of the cathode.

The electron tube shown in FIG. 1 comprises an anode **10**, made of copper for example, and having an exhaust tubulation **12**. The anode defines a space within which are disposed a screen grid **14**, a control grid **16**, and cathode **18**, and a heater **20**. The screen grid **14**, control grid **16** and cathode **18**, respectively have flanges **22**, **24**, and **26**. The flanges serve the dual function of providing desired sealing surfaces and constituting lead-in conductors for the several electrodes with which they are associated.

Suitable sealing and insulating rings are provided between adjacent ones of the electrodes shown in FIG. 1. Thus, between the end edge surface **27** of the anode **10** and

the upper surface of the radially extending portion of flange **22** of the screen grid, is disposed a ring **28** made of a ceramic material such as aluminum oxide. The ends of the rings **28** engaging the anode **10** and flange **22** are suitably metalized with a metal such as molybdenum over which is coated, as by plating, a metal such as nickel for a purpose to be described. Interposed between the metal coating on the upper end of the ring **28** and the anode end surface **27**, and between the lower end of the ring **28** and the flange **22**, is a body of fixing material, such as BT solder which wets the anode end edge surface **27** and the flange **22** as well as the metal coatings on the ring **28**, when heated, and forms a vacuum-tight seal between these elements when cooled.

While the foregoing seals are satisfactory, they may be improved, for example, by interposing rings **29** (FIG. 5) made of an alloy such as Kovar consisting by weight of 29% nickel, 17% cobalt and the balance iron, between the sealing surfaces of the insulating sealing ring **30** and, respectively, the flange of screen grid **14** and the flange of control grid **16**. Such metal alloy more closely approximates the expansion characteristics of the material of the insulating ring than does the metal, usually copper, of which the anode and flange are made.

Seals similar to the ones discussed are also made between the flanges **24** and **26** utilizing an insulating sealing ring **32**, which may be made of a material similar to that of sealing ring **28**. A similar seal is made by means of a sealing ring **28** between flange **22**, and the end edge surface **27** of the anode.

The heater **20** in FIG. 1 is mounted on terminal posts **34**, **36**. Terminal post **36** is fixed to an apertured metal flange **38** fixed to cathode flange **26**. Terminal post **34** is fixed to a metal flange or plate **40**, serving as the terminal lead for one end of the heater. Interposed between the flanges **38** and **40** is a disk or plate **42** of insulating material such as aluminum oxide, suitably metalized as a forementioned, for sealing to the flanges or plates **38**, **40**.

In the tube structure shown in FIG. 1, the cathode **18**, control grid **16** and the screen grid **14** are shown with openings **43**, **44**, **46** at their upper ends. These openings are provided on the axes of these electrodes to facilitate jigging the electrodes into concentric relation.

The cathode **18** has a structure comprising a base (core) made of nickel, for example, and having a plurality of spaced fingers **48** having an inner surface coated with a matrix **50** of metal particles such as nickel, suitably impregnated with an emitting material such as mixture of the oxides of barium, strontium and calcium, as shown in FIGS. 2 and 3. The fingers **48** are in radial register with the sleeve segments **49**, **51** of grids **14**, **16**. Between the fingers **48**, portions of the impregnated matrix **50** are exposed. This arrangement limits electron emission only to the regions of exposed matrix recessed between the fingers **48**, emission from adjacent regions being blocked by the fingers **48**. This structure results in a rugged long-life cathode contributing to a desirable beaming function.

While only four fingers **48** are shown in FIGS. 2 and 3, for clarity reasons, many more fingers may be used. In one example, eighteen fingers were provided. Furthermore, the matrix **50** need not cover the outer surfaces of the fingers **48**, as shown in FIGS. 1, 2, and 3 but may be restricted only to the inner surfaces thereof and to the regions between the fingers.

The cathode **18** may be made by a technique illustrated in FIG. 4. Thus, a cathode blank **52**, which may or may not be slitted to provide fingers therein, is positioned inverted fashion in a jig comprising a container **54** having an embossment **56** in the bottom thereof corresponding in size to the opening **43** in the blank. A rod **58** is positioned within the cathode blank and has a recess **60** for receiving the embossment **56** and for wedging the lower end wall of the blank between the rod **58** and the bottom wall of container **54**.

The rod **58** should have a smaller diameter than the

inner diameter of the cathode blank **52** as shown in FIG. 4 for a reason that will become apparent. While the inner diameter of the container **54** is appreciably larger than the outer diameter of the cathode blank as shown, it may be preferable in some cases, to provide a snug fit between the cathode blank and container.

After a positioning of the cathode blank **52** on the jig **54**, **58**, as shown in FIG. 4, a quantity of metal particles, such as nickel, are poured into the annular spaces **62**, **64**. The nickel particles may be in a commercially available powder form. The portion of the metal particles in space **64** may be determined by a shoulder **65**, and by the amount of metal particles poured. If a snug fit exists between the cathode blank and the container **54** the annular space **64** will be eliminated. It is preferable to pour an amount of metal particles so that the volume thereof will result in a body extending axially parallel along what is to be the active portion only of the cathode. However, it is tolerable to have the volume of metal particles extend into engagement with the inner surface of the lower end wall of the cathode blank, as shown in FIG. 4, to facilitate manufacture.

After the metal particles have been poured into and compacted in the space **62** alone, or in the two spaces **62**, **64**, the jig with the parts thereon, is placed in an oven and first heated in wet hydrogen to a temperature of about 1100° C. for from 15 minutes to one hour for presintering the metal particles. The cathode blank with the metal particles sintered thereto, is then removed from the jig and subjected to an oven temperature of about 1200° C. in dry hydrogen, for from 15 minutes to one hour, to complete the sintering operation.

The jig is preferably made of an alloy known as Nichrome which consists by weight of from 19 to 20% chromium, 1% iron, 0.25% manganese, 0.10% carbon, 0.45% silicon, 0.10% aluminum and the balance nickel. This alloy responds in oxidation to the presence of wet hydrogen. The oxide on the jig facilitates removal of the workpiece therefrom after the first of the aforementioned heat treatments is completed.

The cathode so made is then fixed in a sub-assembly by mounting on a suitable jig (not shown), parts comprising the cathode **18**, the control grid **16**, screen grid **14** and metalized ceramic rings **30**, **32**, with BT solder between the engaging surfaces of these parts, for disposing these parts in accurate coaxial relation. The parts so mounted are then heated in an oven to a temperature of 820° C. for softening the solder between the engaging surfaces of the parts, and brazing the parts together. The resultant brazed sub-assembly **63** is shown in FIG. 5.

The brazed sub-assembly **63** is next subjected to an erosion procedure for removing elongated portions of the two grids, and to form grooves in the cathode. In the event the cathode has not been provided with fingers in a prior step, the formation of the grooves in the cathode involves complete removal of the material of the cathode blank at the regions of the grooves and also, preferably, a removal of a portion of the sintered body within the cathode blank of said regions. If there are slits already in the cathode base, the sintered body may extend continuously from the inner to the outer surface of the cathode blank through the slits, and the outer portions of the sintered body at the slitted regions are eroded away leaving only a recessed inner shell or layer of sintered material.

The erosion step may be carried out in the manner described in U.S. Patent 2,980,984 to M. B. Shrader et al. and referred to before herein. Thus, as shown in FIG. 5, the cathode-grid sub-assembly **63** is positioned on a support **66** within a tank **68** containing a suitable dielectric liquid, such as deionized water, to level **70**. Supported to be vertically movable above the sub-assembly **63** referred to, is an eroding broach **72** having teeth or fingers **74** equal in number to the number of eroded regions to be provided in the workpiece. The fingers **74** are disposed

in a circular array coaxial with the sub-assembly **63**, with the fingers **74** extending radially in said array. The fingers **74** have a radial extension for extending through the two grids **16, 14**, and partly through the sintered portion of the cathode **18** as it is brought down. The fingers **74** extend a sufficient distance inwardly, toward the center of the array, so as to engage the base portion of the cathode, to remove all except the inner sintered layer. The tool is preferably not lowered beyond the lower extent of the sintered material. The remaining portions of the matrix **50** which are in radial register with the removed portions of the grids and the base portion of the cathode, suffice for service as the active cathode portions, as will appear in the following.

The selective erosion of the work piece **63** shown in FIG. 5 occurs as the broach **72** is lowered into attempted engagement with the workpiece. Before engagement occurs, however, electrical discharges between the broach and workpiece advance an erosion zone downwardly as viewed in FIG. 5. The erosion may be permitted to proceed to a location slightly above the lower end of the matrix **50**. In this way, the matrix covers fully the slits or openings in the cathode blank produced by the broach **72**. Consequently, there is no spillage of the emitting material through the cathode during application of an emitting material in a manner to be described. To permit the erosion zone to pass below the matrix, as viewed in FIG. 5, would result in exposed openings below the matrix through which coating material might spill during application, and might contaminate the grids.

The electrical discharges referred to, occur in response to a potential difference between the broach **72** and the workpiece, produced by connecting leads **76, 78** to sources of potential difference.

It will be noted that the length of the broach fingers **74** is not affected whether or not the cathode blank **52** (FIG. 4) has been provided with fingers or strips prior to the erosion step. Since a pre-forming of such fingers in the cathode blank would require a high degree of care in later orienting the workpiece during the erosion step, to assure a register of the broach fingers with the slits in the cathode blank, it is preferable to provide the cathode fingers simultaneously with the formation of apertures in the two grids.

After completion of the electrical erosion step described, a top view of the cathode appears as shown in FIG. 3. As will be noted, the erosion step has produced grooves or recesses **80**, and has involved complete removal of the portions of the sintered body **82** on the outer surface of the cathode, as well as removal of the material of the cathode blank **52** (FIG. 4), at the regions engaged by the fingers of the broaching tool. However, the broaching tool fingers **74** do not extend fully through the composite body made up of the cathode blank material and the sintered body. Thus, there remains at the broached regions a relatively thin body **84** of the matrix **50**, the surfaces of which provide active cathode areas. The broaching tool also forms slots **86, 88** in the grids **16, 14**, in radial register with the recesses **80** in the cathode.

Following the erosion step described, the anode **10** is brazed to the screen grid flange **22**, by interposing between the sealing surfaces of the anode and the flange, a suitably metalized and coated insulating ring **28** and BT solder of the type previously described. The anode **10** and the sub-assembly **63** with the sealing ring **28** and solder referred to, are suitably jigged in coaxial relation and heated in an oven for brazing the anode to the sub-assembly referred to, to provide the anode-cathode-grid sub-assembly **90** shown in FIG. 6.

It will be noted that the last mentioned sub-assembly has an opening **92** at one end communicating with the inner surface of the cathode **18**. This opening is utilized in coating the inner surface of the matrix body **50** with electron emitting material.

During a coating operation, sub-assembly **90** is supported in a jig **94** mounted for rotation on the axis of sub-assembly **90**. A conduit **96** extending from a reservoir **98** is provided with a nozzle **100** (which may have a plurality of openings), adapted to extend into the interior of the cathode **18**.

The coating material dispensed by nozzle **100** may consist of two parts by volume of a coating suspension described in column 3 lines 36 to 65 in U.S. Patent 2,800,446 to M. N. Fredenburgh, issued July 23, 1957, and one part of acetone. The coating suspension referred to, includes the carbonates of barium, strontium and calcium suspended in a medium comprising acetone, dibutyl phthalate, and polymeric methyl methacrylate. The resultant coating material has a thin cream consistency.

During a dispensing of the coating material by the nozzle **100**, the jig **94** is rotated at a velocity of from 200 to 1,000 r.p.m. for a period of from one-half to one minute. This rotation of the dispensed coating material, provides a centrifugal force which is supplemented by capillary action, for effectively dispersing the material entirely through the pores of the matrix **50**. Applicant has found that the degree of penetration into the matrix pores of the coating material is dependent upon the drying time of the solvent (acetone). If this drying time is of the order of one hour, the capillary force is taken advantage of fully and an equilibruim occurs between the forces urging entry of the material into the pores of the matrix, and the forces that oppose such entry, when full entry of the material has taken place. If the forces of entry are too great and the equilibrium is overcome in the penetrating direction, material may be lost or sprayed to contaminate the grids. If the forces of entry are not sufficient, full penetration of the cathode is not achieved. The coating composition described has an important drying time characteristic that permits attainment of the aforementioned equilibrium under the conditions specified.

After the coating has dried, the heater sub-assembly is sealed across the opening **92** (FIG. 6). The heater sub-assembly, as shown in FIG. 1, comprises an insulatingly coated heater coil **20** fixed at one end to conducting rod **34** and at the other end to conducting rod **36**. The rod **34** is sealed through the flanged metallic plate **40** while rod **36** is fixed to flanged member **38**. The plate **40** is fixed to the flanged member **38** by means of the insulating plate **42**, made of aluminum oxide, for example, and having suitably metalized and coated surfaces for brazing to the plate **40** and flanged member **38**. The fixing of these parts may be effected in an oven prior to incorporation of the sub-assembly in the tube structure.

The assembling of the heater sub-assembly in the tube structure involves extending the heater **20** (FIG. 1) into the opening **92** (FIG. 6) until the flanged member **38** is seated in flanged member **26**. When so seated, the edges **106, 108**, are substantially in a plane normal to the tube axis. In this position, the edges referred to are mutually fixed by locally applied heat, such as by heliarc welding.

The interior of the tube is then evacuated to a suitably low pressure through the exhaust tubulation **12**, which may be made of copper for example, and the tubulation is then closed as by pinching for providing a cold-welded closure.

While it has been mentioned in the foregoing that the matrix **50** may be applied to the inner surface alone of the cathode blank, or to both the inner and outer surfaces thereof, and that in either case, portions of the matrix are removed in an erosion step, it is feasible to practice the invention without removing any portion of the matrix. It is essential however, that the cathode blank be slitted to provide the fingers **48**. Where no portion of the matrix is removed, the coating material applied to the inner surface of the cathode, will become diffused by capillary action throughout the entire matrix body, by passing through the slits between the fingers **48**. In

this example where no matrix material is removed, the radial register of the cathode slits with openings in one or more associated concentric grids, is not critical, since substantially uniform emission is produced from the finished cathode throughout the entire continuous outer surface of its active portion. However, in this example simplicity of manufacture is achieved at the cost of a desired beaming action obtained when portions of the matrix are removed, as described in the foregoing.

I claim:

1. Method of making an electron tube comprising
(a) mutually fixing in relatively close spaced relation to a tubular cathode having openings in the side wall thereof bridged by a metal matrix, within a tubular grid, and thereafter
(b) dispensing emitting material to the inner surface of said matrix for migration through said matrix to the outer surfaces of said matrix in said openings.

2. Method of making an electron tube comprising
(a) mutually fixing by oven brazing a tubular cathode blank having pores, and two imperforate tubular grid blanks surrounding said cathode,
(b) simultaneously eroding radially registering openings in said grid blanks, and depressions in the outer surface of the cathode blank to provide two grids and beam forming areas on said cathode blank,
(c) fixing by oven brazing a tubular anode to the outermost of said grids,
(d) dispensing electron emitting material to the inner surface of said cathode for migration through said pores to the outer surface of said cathode at said depressions only,
(e) mounting a heater assembly within said cathode and sealing said assembly across one end of said cathode, thereby closing one end of an envelope for said tube, and
(f) evacuating said envelope through the other end thereof and sealing said other end.

3. Method of making a tubular cathode comprising
(a) forming axially extending slits around an axial portion of a metallic tubular cathode blank,
(b) compacting relatively small metallic particles around the entire of said axial portion and bridging said slits,
(c) sintering said particles to form a matrix having pores of capillary size, and
(d) depositing an emitting material over the matrix surface within said cathode blank, said material including a vaporizable thinner in sufficient amount to keep said material in a sufficiently low viscous state for a time interval long enough to permit said material to fully penetrate said pores.

4. Method of making a cathode-grid subassembly for an electron tube comprising:
(a) forming a closely adhered coaxial matrix of sintered metal particles on an inner wall of a portion of a tubular cathode blank,
(b) mutually fixing said tubular cathode blank and an imperforate tube grid blank around the cathode blank,
(c) eroding openings through said grid blank, and
(d) eroding openings in said portion of the cathode blank in radial register with said grid blank openings while preserving said matrix from erosion.

5. Method of making a tubular cathode comprising:
(a) forming on a tubular cathode blank a wall portion consisting solely of a sintered metal matrix body having pores of capillary size,
(b) depositing an electron emitting material on said wall portion within said cathode blank and wherein said material includes a vaporizable thinning liquid adapted to keep said material below a predetermined viscosity for a predetermined interval of time, and
(c) axially rotating said cathode at a predetermined speed for causing said electron emitting material to pass through said matrix body to the outer surface thereof during said interval of time.

References Cited by the Examiner

UNITED STATES PATENTS

2,501,089	3/1950	Pomerantz	313—337
2,543,728	2/1951	Lemmens et al.	313—337
2,647,216	7/1953	Brown	313—346.1
2,808,530	10/1957	Katz	313—346.1
2,879,429	3/1959	DeSantis et al.	313—293
2,932,759	4/1960	Sheperd	313—337
2,952,789	9/1960	McCullough et al.	313—250 X
2,980,984	4/1961	Shrader et al.	29—25.16 X
3,007,760	11/1961	Knauf et al.	29—25.17 X
3,146,515	9/1964	Raglund	29—25.17

JOHN F. CAMPBELL, *Primary Examiner.*

JOHN W. HUCKERT, *Examiner.*

ROBERT SEGAL, WHITMORE A. WILTZ, *Assistant Examiners.*