March 19, 1968 F. M. CHARBONNIER ETAL 3,374,386

FIELD EMISSION CATHODE HAVING TUNGSTEN MILLER INDICES
100 PLANE COATED WITH ZIRCONIUM, HAFNIUM
OR MAGNESIUM ON OXYGEN BINDER

Filed Nov. 2, 1964

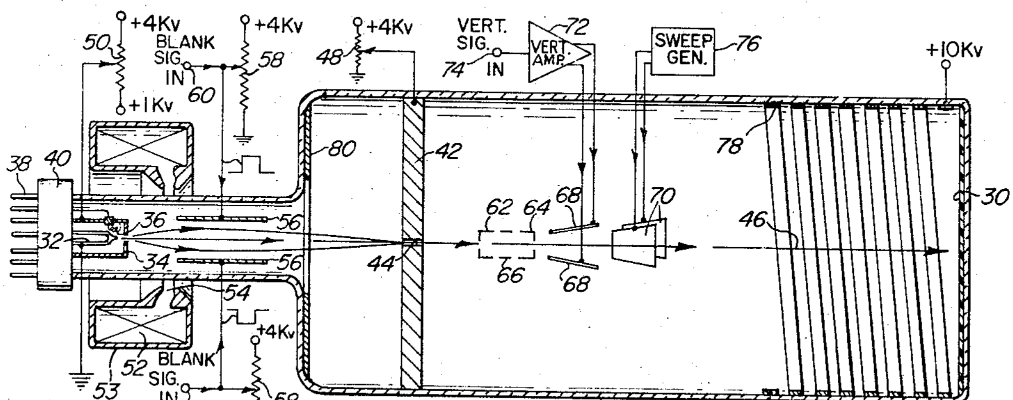

Fig. 1

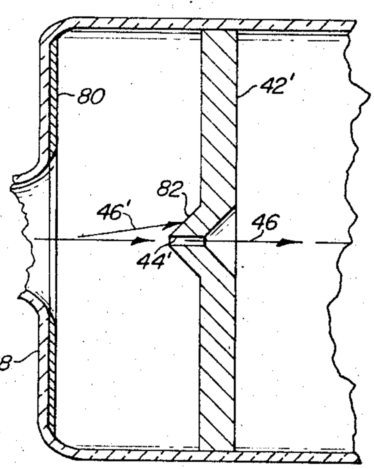

Fig. 2

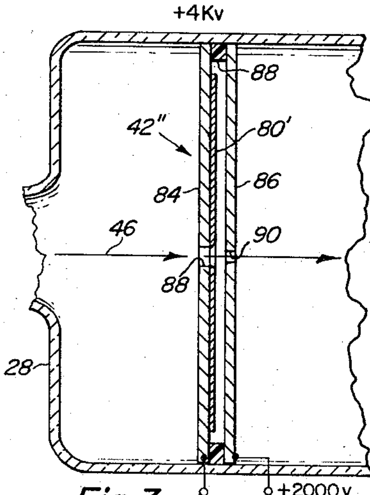

Fig. 3

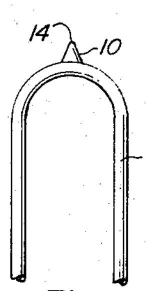

Fig. 4

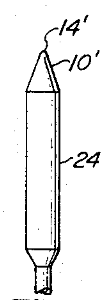

Fig. 5

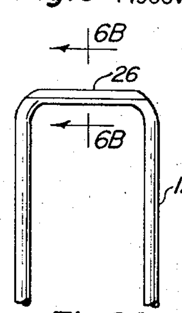

Fig. 6A

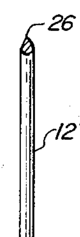

Fig. 6B

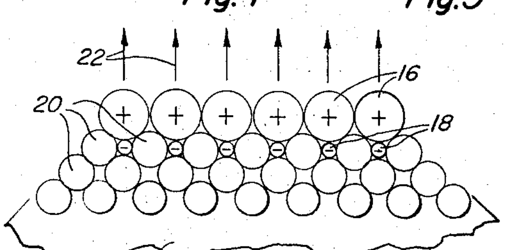

Fig. 7

FRANCIS M. CHARBONNIER
EUGENE E. MARTIN
LYNWOOD W. SWANSON
INVENTORS.

BY

BUCKHORN, BLORE, KLARQUIST & SPARKMAN
ATTORNEYS

United States Patent Office

3,374,386

Patented Mar. 19, 1968

1

3,374,386

FIELD EMISSION CATHODE HAVING TUNGSTEN MILLER INDICES 100 PLANE COATED WITH ZIRCONIUM, HAFNIUM OR MAGNESIUM ON OXYGEN BINDER

Francis M. Charbonnier, Eugene E. Martin, and Lynwood W. Swanson, McMinnville, Oreg., assignors to Field Emission Corporation, McMinnville, Oreg., a corporation of Oregon

Filed Nov. 2, 1964, Ser. No. 408,035

9 Claims. (Cl. 313—34.6)

The subject matter of the present invention relates generally to field emission cathodes and electron beam devices employing such cathodes, and in particular to an electron gun structure using such cathode in a cathode ray tube to produce a narrow electron beam of high current density, low divergence, and small source area by confining the emission of electrons from the field emission cathode in such gun structure to a predetermined crystal plane on the point of such cathode.

The field emission cathode and electron gun of the present invention is especially useful when employed in a cathode ray tube for an oscilloscope but can also be used in other electron beam devices such as an electron microscope or a charge image storage tube. In addition to those mentioned above, the field emission cathode and electron gun structure of the present invention has several other advantages over previous cathodes and gun structures of this type including a longer lifetime and more stable emission from a smaller source area on the cathode. In addition, the electron gun of the present invention also operates more efficiently to produce a beam of greater current density. This also enables better image resolution and a higher writing rate when such gun is employed in a cathode ray tube, as well as the use of a lower blanking voltage for preventing the beam from reaching the fluorescent screen of such tube. Another advantage of the electron gun of the present invention is that the evacuated envelope containing such gun may be divided into two chambers of different pressure so that the chamber containing the cathode is at a lower pressure than the chamber containing the phosphor screen, storage target or microscope specimen. Of course, any tube employing a field emision cathode has an additional advantage over a conventional tube in that no heater voltage supply is required for the cathode except during activation of such cathode, and the tube requires no warm-up time before the cathode begins emitting electrons and such tube begins operation.

Briefly, one embodiment of the cathode of the present invention is a tungsten rod having a conical tip portion with a layer of oxygen and zirconium coated on the point of such tip portion. The tungsten cathode is constructed so that the plane of the cubic, body centered crystal lattice structure of tungsten having Miller indices 100 is oriented at the tip of such cathode. It has been discovered that if a coating of zirconium is applied to the cathode and such cathode is heated, the zirconium atoms will migrate to the 100 atomic plane at the point of the tungsten cathode. Since zirconium has a lower work funcion than tungsten, the field emission of electrons from the cathode will be confined substantially entirely to the 100 plane at the tip of such cathode. In addition, it has been found that if an intermediate layer

2

of oxygen is provided on the cathode tip before the zirconium layer is applied thereto, such zirconium layer adheres to the 100 plane for a much longer time than when such oxygen is not employed. While it is not entirely understood why this occurs, it is believed that it is the combined effect of an electrical attraction between the atoms of the various elements because of their different electrical charges shown by their displacement from each other in the electromotive series of elements, the geometrical fit of the oxygen and zirconium atoms in the 100 lattice plane of tungsten and the relative physical size of the atoms themselves that holds the zirconium atoms in position after such zirconium atoms have once migrated to the 100 plane.

The field emission cathode described above is positioned within a tubular control electrode or grid in one embodiment of the electron gun structure of the present invention, and supported to direct the beam emitted by such cathode through an aperture in a collimating electrode which has a pasageway through such plate of greater length than diameter to reduce the divergence of such beam. In addition, a pair of blanking deflection plates may be provided on opposite sides of the electron beam path between the control electrode and the collimating electrode within one chamber of the envelope of the cathode ray tube. A conventional electrostatic focusing structure including first and second anodes and a focusing electrode can be positioned within the other chamber of the envelope between the collimating electrode and a fluorescent screen on the face plate of such tube. Two pairs of horizontal and vertical deflection plates are supported within the tube envelope between the electrostatic focusing structure and the phosphor screen for deflecting the electron beam before it strikes such screen. In addition, a small electromagnetic focusing coil is positioned about the neck of the tube envelope adjacent the field emission cathode in order to focus the beam emitted by such cathode to a narrow cross section before such beam is transmitted through the collimating electrode. Also a layer of getter material may be provided within the envelope inside the chamber containing the field emission cathode in order to reduce the pressure within such chamber below that of the other envelope chamber containing the phosphor screen.

It is therefore one object of the present invention to provide an improved field emission cathode which emits an electron beam from a small predetermined portion of such cathode and which can be operated continuously for a long useable lifetime.

Another object of the present invention is to provide an improved field emission cathode having a pointed tip or edge portion which is coated with a low work function material only on a predetermined crystal plane of such portion to emit a narrow beam of electrons of less divergence.

A further object of the present invention is to provide an improved electron gun employing a field emission cathode efficiently to produce an electron beam of smaller cross section, less divergence, and a greater current density.

An additional object of the present invention is to provide an improved electron beam device having an electron gun which employs a collimating electrode between a field emission cathode and a phosphor screen or other target in such envelope to divide the envelope into two chambers containing such cathode and such target and enable such chambers to be operated at greatly different pressures and to reduce the divergence of the electron beam emitted from such cathode and transmitted through the aperture in such collimating electrode.

Still another object of the present invention is to provide an improved cathode ray tube employing a field emission cathode which has a long stable lifetime so that such tube requires no heater supply voltage and no warm-up time, has a higher writing rate, better image resolution and can use blanking signals of lower voltage for preventing the electron beam from striking the fluorescent screen of such tube.

Other objects and advantages of the present invention will be apparent from the following detailed description of certain preferred embodiments thereof, and from the attached drawings of which:

FIG. 1 is a schematic view of one embodiment of a cathode ray tube having an electron gun made in accordance with the present invention;

FIG. 2 is an enlarged section view of a portion of an electron gun similar to that of FIG. 1 in which another embodiment of collimating electrode is employed;

FIG. 3 is a view similar to FIG. 2 except that a third embodiment of the collimating electrode is shown;

FIG. 4 is an enlarged view of one embodiment of a field emission cathode made in accordance with the present invention;

FIG. 5 is an enlarged view of another embodiment of the present field emission cathode;

FIG. 6A is an enlarged view of a third embodiment of the field emission cathode of the present invention;

FIG. 6B is a vertical section view taken along the line 6B—6B of FIG. 6A; and

FIG. 7 is a schematic view of the tip portion of the field emission cathodes of FIGS. 4, 5, or 6A diagrammatically illustrating the electron emissive coating on the surface of such tip portion.

One embodiment of the field emission cathode of the present invention is shown in FIG. 4 and includes an electron emitting portion **10** attached to a support filament **12** which is employed to heat such emitting portion during the coating process hereafter described. The support filament **12** may be formed of a tungsten wire bent into a U-shape, and the electron emitting portions **10** formed of monocrystalline tungsten in the shape of a cone having a half angle of approximately 15° which is sufficiently large to exclude strong emission from sites other than at the cathode tip. The conical cathode portion **10** is provided with a sharpened portion in the form of a pointed tip **14** having a radius of curvature in the range of approximately 10^{-4} to 10^{-7} centimeters to enable the establishment of the high electrical field at such tip necessary for field emission of electrons.

The pointed tip **14** of the electron emitting portion **10** of the cathode has an electron emissive coating thereon, as shown in FIG. 7. This coating which is provided only on the sharpened tip portion **14** includes a layer **16** of low work function material such as zirconium and an intermediate layer **18** of bonding material such as oxygen. The cathode portion, composed of tungsten, oxygen and zirconium, has a field emission work function of about 2.6 electron volts at room temperature, while that of tungsten alone is approximately 4.5 electron volts. The atoms of zirconium are of the proper size to "fit" into the spaces between the atoms **20** of tungsten at the surface of tip **14** on the tungsten crystal lattice plane having Miller indices 100. The zirconium atoms deposited on the cathode migrate to the 100 crystal lattice plane of tungsten oriented at the surface of the sharpened cathode tip portion and apparently the region on the tip immediately surrounding such plane after the cathode is heated by current flowing through filament **12** or in some other suitable manner, and cause electrons **22** to be emitted only from the small area on the tip of the 100 plane and such surrounding region. It has been discovered that a coating of oxygen atoms **18** on the cathode will bond the zirconium atoms more securely to the 100 plane on the cathode tip to provide a longer stable emission lifetime for such cathode. This bonding is apparently caused by their geometrical fit in the 100 plane and by electrical attraction between the atoms of these elements due to their different electrical charges shown by their large displacement from each other in the electromotive series of elements which lists zirconium and tungsten as electropositive elements and oxygen as an electro-negative element. Another cathode having similar characteristics to that just described can be formed by substituting carbon for oxygen as the layer **18**. In addition to the materials described above, hafnium or magnesium may be employed as the low work functional material **16** because they fit the 100 plane of tungsten, and nitrogen, chlorine, iodine or fluorine can be used as the bonding material **18**. Thus, other suitably charged elements as listed in the electromotive series can be employed in layers **16** and **18** if they have the proper electrical charge and proper atomic size to "fit" on one of the crystal planes of the tungsten substrate.

Also, it is possible to replace the zirconium with other electron emitting material such as cesium, barium or thorium which adheres to both the 100 and 211 planes of the tungsten lattice. However, these other electron emissive materials have a disadvantage in that they would form a plurality of spaced sources on the cathode for the electrons **22** emitted therefrom due to the fact that such material adheres to several different planes. Such a multispot source of electrons is usually undesirable since most electron beam devices require a point source for proper focusing of such beam. However, it is conceivable that a cathode could be constructed wtih only one of such planes positioned at the tip portion having a small radius of curvature so that electron emission is limited to such point. Of course, other refractory metals having cubic crystal lattice structures and atomic size similar to tungsten, such as molybdenum, platinum or nickel, and even semiconductor materials such as silicon or diamond can be employed for the substrate body **14** of the field emission cathode in which case other low work function materials would be employed for layer **16**, and other bonding materials can be employed in layer **18**.

In addition to the filament supported cathode of FIG. 4, it is also possible to provide a field emission cathode **24** of tungsten having an enlarged cylindrical body portion with a conical point **10'**, as shown in FIG. 5. The tip **14'** of cathode point **10'** is coated with a layer of electron emissive material and bonding material similar to that shown in FIG. 7. The cathode **24** can be indirectly heated by a high frequency induction coil in order to cause the zirconium coated on the cathode portion **10'** to migrate to the 100 plane oriented at cathode tip **14'**. Of course, any other suitable method of indirect heating can also be employed including electron bombardment from another source.

In addition to the pointed cathodes of FIGS. 4 and 5, the cathode of the present invention may also be formed with an elongated sharpened knife edge **26** shown in FIGS. 6A and 6B. This knife edge cathode may be provided on the filament wire **12'** after bending such filament wire into the rectangular shape and sharpening the outer side of the intermediate portion of such filament wire. The 100 crystal plane of the tungsten substrate material can be oriented at the sharpened tip of the knife edge, and then coated with an electron emissive layer similar to that shown in FIG. **7** by causing heating curent to flow through support filament **12'**.

One embodiment of a cathode ray tube employing an electron gun having a field emission cathode made in accordance with the present invention is shown in FIG. 1. This tube includes an evacuated tubular envelope **28** of glass or other suitable insulating material having a fluorescent screen **30** coated on the inner surface of the face plate portion of the envelope at one end of the tube and a field emission cathode **32** mounted within the envelope at the other end of the tube. The cathode **32** provides a small point source of electrons and may be either of the cathodes of FIGS. 4 and 5 previously described. This field emission cathode is positioned within a tubular control electrode or grid **34** having a small aperture therein for the passage of electrons emitted from the tip of such cathode. A wire **36** of solid zirconium or having a coating of zirconium extends through an opening in the side of the control electrode **34** and is coiled inside such control electrode in a position adjacent the tip of the cathode. The wire **36** is heated by electrical current passed through such wire to vaporize the zirconium and cause the zirconium vapor to be deposited upon such cathode tip but not on the glass envelope due to the shielding effect of the control electrode. One terminal of the zirconium wire **36** may be connected to the inside wall of the control electrode, while the other terminal of such wire extends through an insulating plug in the opening through the side of the control electrode and is connected to one of a plurality of metal terminal pins **38** extending through the envelope and secured in a socket **40** attached to the base of the tube envelope for the application of heating current to such wire. In a similar manner, the opposite ends of the cathode support filament are connected to a different terminal pins **38** for enabling the flow of heating current therethrough when the cathode **32** is in the form of the cathode shown in FIG. 4. It should be noted that the oxygen absorbed in the cathode may be provided by heating a crucible containing an oxygen compound such as copper oxide, supported inside the envelope adjacent such cathode to decompose the compound and liberate oxygen within the envelope in the immediate vicinity of the cathode. However, there is usually enough residual oxygen left within the tube envelope during its manufacture to cause sufficient oxygen to be absorbed by the field emission cathode to bond the zirconium or other low work function material to the cathode tip if the cathode is coated with zirconium before the tube is degassed in a conventional manner.

A collimating electrode **42** is supported within the envelope between the control electrode **34** surrounding cathode **32** and the fluorescent screen **30** in any suitable manner in order to divide the envelope into two separate pressure chambers, such as by a metal ring (not shown) of Kovar extending through the envelope to provide a gas-tight glass to metal seal around the periphery of such collimating electrode. This collimating electrode may be in the form of a flat circular metal plate of substantial thickness having an aperture **44** through the center of such plate to enable the passage of the electron beam **46** emitted by the cathode **34** through such collimating electrode. The electron passageway **44** may have a diameter on the order of .004 inch and a length of about .04 inch. This reduces the amount of gas transmitted through the collimating electrode and provides some collimating effect on the electron beam **46** so that the maximum divergence of such beam is only about one degree after it is magnified by the electromagnetic focusing coil and passes through such collimating electrode.

The collimating electrode **42** is connected to the movable contact of a potentiometer **48** whose end terminals are connected between a positive D.C. voltage source of +4 kilovolts and ground to apply a D.C. voltage which may be in the neighborhood of +2 kilovolts to such electrode and is substantially equal to the voltage applied to the control electrode **34** by the movable contact of another potentiometer **50** whose end terminals are connected between positive D.C. voltage sources of +4 kilovolts and +1 kilovolt. After the electron emissive coating is applied to the cathode **32**, such cathode is grounded so that the potential difference between the cathode and the control electrode **34** causes the field emission of electrons from such cathode at the tip thereof. Of course, other potentials can be applied to these electrodes. For example, the collimating electrode **42** can be grounded and the cathode connected to a negative D.C. voltage which may be varied between −2 kilovolts and −4 kilovolts. As stated previously, the layer **16** of zirconium or other low work function material limits electron emission from the tungsten cathode to the 100 plane at the tip of such cathode so that such beam originates from an extremely small source and of less divergence.

An annular electromagnetic focusing coil **52** is positioned about the neck of the envelope between the control electrode **34** and the collimating electrode **42** in order to focus the electron beam after it emerges from the aperture in the control electrode. The magnetic core **53** of the focusing coil is provided with inward projecting portions to position the gap **54** between the north and south poles of such core closer to the envelope to achieve maximum field adjacent the axis of the tube so that the electron beam is focused to a point just inside the inlet opening of the passageway **44** through the collimating electrode. In addition, the electron gun may be provided with a pair of blanking deflection plates **56** which are supported within the tube envelope between the control electrode **34** and the collimating electrode **42** in order to move the electron beam out of alignment with the aperture in the collimating electrode to prevent such beam from striking the fluorescent screen **30**. In this regard the blanking plates **56** are each connected to the movable contact of a different potentiometer **58** whose end terminals are connected between a positive D.C. voltage source of +4 kilovolts and ground in order to apply substantially the same D.C. potential to such blanking plates that is applied to the collimating electrode **42**. A push-pull blanking signal having an amplitude of from 20 to 50 volts is applied to the blanking plates **56** through separate input terminals **60** connected to such plates.

A conventional electrostatic lens structure including a first anode **62**, a second anode **64** and a focusing electrode **66** is mounted within the tube envelope between the collimating electrode and the fluorescent screen **30**. In addition, a pair of vertical deflection plates **68** and a pair of horizontal deflection plates **70** are mounted within the tube envelope between the lens structure including electrodes **62**, **64**, **66** and the fluorescent screen **30** in order to deflect the electron beam **46** in accordance with signals applied to such deflection plates before such beam strikes such fluorescent screen. The vertical deflection plates **68** are connected to the push-pull output of a vertical amplifier **72** whose input is connected to a source of vertical signals at input terminal **74**, while the horizontal deflection plates **70** are connected to the push-pull output of a horizontal sweep generator **76** which may be triggered into operation by a trigger pulse produced by the vertical input signal in a trigger generator circuit, not shown. In order to increase the brightness of the light image produced on the fluorescent screen **30**, post deflection acceleration of the electron beam can be employed by providing a helix wall coating **78** of suitable resistance material, such as a graphite compound, on the inner surface of the envelope between the horizontal deflection plates **70** and the fluorescent screen and connecting the ends of such wall coating between D.C. voltage sources of +4 kilovolts and +10 kilovolts.

As mentioned previously, the collimating electrode **42** divides the envelope into two separate chambers which may be maintained at different pressures due to the extremely small diameter of passageway **44**. Thus, the envelope chamber containing the cathode **32** may be maintained at an extremely low pressure of about 10^{-10} millimeters of mercury by providing a coating of getter material **80** on the inner surface of the envelope in such compartment, while the other compartment containing the fluorescent screen or other target may be maintained at a higher pressure of approximately 10^{-6} millimeters of mercury. This enables conventional materials to be employed for the elements contained in the chamber of higher pressure while increasing the lifetime of the field emission cathode by operating it in the lower pressure chamber. It should be noted that the aperture **44** and the collimating electrode **42** does provide a slow leak which would eventually equalize the pressure in the compartments were it not for the presence of getter material **80** and the ion pumping action of the electron beam.

Of course, an electrostatic focusing structure can be substituted in place of the electromagnetic focusing coil **52** but generally has greater aberation, in which case such electrostatic focusing structure would be positioned inside the envelope between the control electrode **34** and the blanking deflection plates **56**. In addition, different types of collimating electrodes may be employed in place of electrode **42** of FIG. 1. Thus, as shown in FIG. 2, a collimating electrode **42'** may be provided having a frustoconical projection **82** in the center of the plate immediately surrounding the passageway **44** and extending toward the cathode. This conical projection **82** prevents any secondary electrons emitted by the rear surface of the collimating electrode **42** when such electrode is struck by the electron beam **46'**, such as during blanking, from passing through the aperture **44** in such plate.

Another form of collimating structure **42''** is shown in FIG. 3 and includes a pair of flat metal plates **84** and **86** which are held in uniform spaced relationship by a spacer ring **88** of ceramic or other insulating material positioned between such plates adjacent the periphery thereof, or by any other suitable mounting structure. The collimating plate **84** nearest the cathode is provided with an aperture **88** through the center thereof having a diameter on the order of .020 inch while the other collimating plate **86** is provided with a central aperture **90** of much smaller diameter of about .004 inch. When this type of collimating structure is employed, the getter layer **80'** may be positioned on the inner surface of one of such collimating plates so that the space between such plates is also maintained at the high vacuum of the cathode chamber. The collimating plates **84** and **86** are each provided with a thickness of about .020 inch and are spaced apart by a distance of about .100 inch. In addition, it has been found that best results are achieved if the electron beam is focused so that the cross-over point occurs just inside the aperture **90** in the second collimating plate.

The "perveance" of the electron beam can be increased if its electrons are decelerated before passing through the collimating electrode structure. This can be accomplished merely by connecting the collimating electrode to a voltage slightly negative with respect to the potential of the control electrode **34**. The effect of such a deceleration is to reduce the loss of electron beam power due to such beam striking the collimating electrode, and to increase the deflection sensitivity of the beam to the signals applied to the deflection plates **68** and **70**.

A tube structure made in accordance with the present invention has produced an electron beam of 10 milliamperes having a beam density of 11 amperes per centimeter squared when using a collimating electrode having an aperture of .008 inch in diameter by operating such collimating electrode and the control electrode at a potential of +1.2 kilovolts with respect to the cathode. This beam could be increased to a current in excess of 100 milliamperes having a beam density of 100 amperes per centimeter squared by increasing the potential of the control electrode and the collimating electrode to about +50 kilovolts.

It will be obvious to those having ordinary skill in the art that various changes may be made in the details of the above-described preferred embodiments of the present invention. For example, materials other than zirconium and oxygen could be used for the layers **16** and **18**, and a material other than tungsten could be used for the substrate body **14**. Also, the electron gun can be made in a form other than the specific embodiments of FIGS. 1 to 3 and can be used in electron beam machining apparatus, electron microscopes and other devices than the cathode ray tubes shown. Therefore, the scope of the present invention should only be determined by the following claims.

We claim:

1. A field emission cathode comprising:
a substrate body of material taken from the group consisting of molybdenum and crystal lattice plane of Miller indices 100 oriented at the surface of a sharpened portion of said body having a small radius of curvature;
a layer containing electron emissive material taken from the group consisting of zirconium, hafnium and magnesium, coated only on said sharpened portion of said body and confined substantially entirely to said lattice plane to reduce the work function of said sharpened portion; and
said layer also containing bonding material, such as oxygen, to cause said emissive material to adhere only to said surface of said sharpened portion so that the field emission of electrons from said cathode forms an electron beam of high current density originating at a small source confined primarily to said coated 100 plane on said sharpened portion of said body.

2. An electron beam tube including the field emission cathode of claim **1** and means for focusing the electrons emitted by said cathode into a narrow beam.

3. The tube of claim **2** which also includes an evacuated envelope having two interconnected chambers of different vacuum pressures and means for mounting the field emission cathode in the chamber of highest vacuum pressure.

4. The tube of claim **3** which also includes a collimating electrode structure mounted within said envelope and having a passageway therethrough which is in communication with both of said two chambers and is in alignment with said cathode.

5. The tube of claim **4** which also includes a fluorescent screen mounted within the chamber of lowest vacuum pressure.

6. The tube of claim **5** which also includes means for deflecting the electron beam so that said tube is a cathode ray tube.

7. The tube of claim **6** which also includes a control electrode positioned between the cathode and the collimating structure, and means for applying a more negative D.C. bias voltage to said collimating structure than to said control electrode to decelerate the electron beam before it is transmitted through the passageway in the collimating structure.

8. The tube of claim **7** in which the collimating structure includes two spaced insulated collimating electrodes maintained at different D.C. voltage potentials, and a layer of gettering material coated on at least one of the collimating electrodes between said collimating electrodes.

9. A field emission cathode comprising:
a body of tungsten including a monocrystalline substrate having a crystal lattice plane of Miller indices 100 oriented at the surface of a sharpened portion of said substrate having a small radius of curvature;
an outer layer of zirconium coated substantially only on the 100 plane of said surface of said sharpened portion of said substrate to reduce the work function of said surface portion; and
an intermediate layer of oxygen coated on said surface portion beneath the outer layer to cause said zirconium layer to adhere only to said surface of said sharpened portion so that electrons emitted

from said cathode originate at a small source confined primarily to said zirconium coated 100 plane.

References Cited

UNITED STATES PATENTS

1,932,084	10/1933	Opsahl	313—77
2,332,622	10/1943	Calbick	313—77 X
2,453,118	11/1948	Buckingham et al.	313—346 X
2,570,124	10/1951	Harnqvist	313—7
2,687,471	8/1954	Buckingham	313—346 X
2,886,736	5/1959	Martin	313—336 X

2,919,380	12/1959	Barnett	313—7 X
2,944,172	7/1960	Opitz et al.	313—7
3,139,541	6/1964	Henderson et al.	313—346 X
3,259,782	7/1966	Shroff	313—336

OTHER REFERENCES

Dyke et al. Field Emission; Advances in Electronics and Electronic Physics; vol. VIII, 1956; pages 126, 161, 137 and 135 cited.

ROBERT SEGAL, *Primary Examiner.*

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,374,386 March 19, 1968

Francis M. Charbonnier et al.

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

Column 4, lines 12 to 14, strike out "Another cathode having similar characteristics to that just described can be formed by substituting carbon for oxygen as the layer 18."; column 8, line 13, after "and" insert -- tungsten having a --; column 9, line 9, for "Harnqvist" read -- Hernqvist --; column 10, after line 4, insert the following:

3,284,657	11/1966	Weissman----313-346
3,289,028	11/1966	Schilling et al---313-82X

Signed and sealed this 22nd day of July 1969.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents