

ANODE FOR AN X-RAY TUBE, A METHOD OF MANUFACTURING THE
ANODE, AND A STATIONARY ANODE X-RAY TUBE

BACKGROUND OF THE INVENTION

(1) Field of the Invention

5 This invention relates to an X-ray tube having a stationary anode (hereinafter referred to as a stationary anode X-ray tube), and more particularly to an anode for use in the stationary anode X-ray tube and a method of manufacturing the anode, and to the stationary
10 anode X-ray tube.

(2) Description of the Related Art

 A stationary anode X-ray tube has no anode revolving mechanism as included in a revolving anode X-ray tube, and therefore has a relatively large heat capacity for its small size. Generally, X-ray tubes are used
15 for medical purposes such as radiographic diagnosis. In surgical operations, however, stationary anode X-ray tubes are used since they are small and light, and hence convenient for transport.

20 Electrical energy is supplied to a target in order to produce X rays, but only 1% of the electrical energy is converted into X-ray energy. The remaining 99% is converted into undesirable heat which brings about a marked temperature increase of the target. Generally,

an anode in a stationary anode X-ray tube includes a cylindrical copper anode base having high heat conductivity, and a disk-shaped anode target embedded in an inclined surface at one end of the anode base.

5 Two methods have been practiced heretofore for manufacturing such anodes. These are "casting method" and "brazing method". Fig. 1 shows a section of an anode manufactured by the casting method. Fig. 2 shows a section of an anode manufactured by the brazing
10 method.

In the Casting Method, an anode target 2 formed of molybdenum (Mo) or tungsten (W) is placed in the bottom of an anode base forming crucible. Then, molten copper is poured into the crucible to form an anode base 1.
15 In this way, the target 2 and base 1 are integrated.

In the Brazing Method, an anode base 1 is prepared in advance, with a recess 3 formed in an inclined surface thereof for receiving an anode target 2. Then, an appropriate solder 4 is applied to the bottom
20 surface of recess 3, and the target 2 is fitted in the recess 3. Subsequently, the anode is heated to join the target 2 to the base 1 through the solder 4.

The above conventional methods have the following drawbacks.

25 In the Casting Method, copper to form the anode

base 1 is heated above a melting point by high frequency heating, with a burner, or the like. This process requires a large amount of energy and results in high cost. Further, this method needs a crucible and the
5 like for forming the anode base 1, and these devices have poor durability to increase the cost of anode base manufacturing. Moreover, the worst drawback of this method is that the cohesion between base 1 and target 2 is weak and unstable, resulting in low heat conductivity. This is due to a low degree of metal-to-metal
10 conformability between base 1 formed of copper and target 2 formed of a metal of high melting point (e.g. tungsten). That is, copper and tungsten, essentially, have low wettability, and do not form an alloy layer
15 when combined together. With an X-ray tube prepared in such a condition, a slight overload causes cracks or fusion in the target surface, and in an extreme case peeling of the target.

In the Brazing Method, bubbles are formed between
20 target 2 and base 1 in time of brazing. These bubbles are mainly responsible for peeling of the target under a thermal stress of repeated load or for cracks or fusion in the target surface due to reduced heat conductivity. Further, the melting point of the
25 solder, essentially, determines a maximum use

temperature of the anode, which results in a lower critical use temperature than where target 2 and base 1 are directly joined together. In addition, a low with-standing voltage is caused by impurities having mixed
5 into gaps between target 2 and base 1 or by a field concentration occurring in such gaps.

SUMMARY OF THE INVENTION

This invention intends to provide an anode for an X-ray tube, a method of manufacturing the anode, and a
10 stationary anode X-ray tube, which eliminate the drawbacks noted above.

The above object is fulfilled, in one aspect of this invention, by an anode for use in a stationary anode X-ray tube, comprising:

15 an anode base with a recess formed in an end surface thereof and having an upwardly diverging inner peripheral wall; and

an anode target formed in the recess by directly fixing therein an anode target material by chemical
20 vapor deposition (CVD).

According to this invention, an anode target is formed by directly fixing an anode target material by chemical vapor deposition in a recess formed in an end surface of an anode base. The target thus formed has

strong adherence to the anode base. Consequently, heat conductivity from the target to the anode base is enhanced, and the target is highly durable against intense thermal loads.

5 In the case of an anode for an X-ray tube obtained in the conventional "casting method" or "brazing method", as shown in Figs. 1 and 2, an end surface of anode base 1 must define a recess (which may inevitably be formed) for embedding anode target 2. However,
10 where an anode target is formed by a method according to this invention, i.e. by chemical vapor deposition, it is not absolutely necessary to form a recess in the end surface of the anode base. This is because an anode target may be formed by depositing an anode
15 target material over an entire leveled end surface of the anode base. However, according to this invention, a recess is formed in the end surface of the anode base and the anode target is formed in the recess by chemical vapor deposition for the following reasons.

20 The first reason is that a relatively thick anode target is efficiently formed. That is, an anode target for use in a stationary anode X-ray tube need to be formed thicker than an anode target for use in a revolving anode X-ray tube. For example, a revolving
25 anode target has a thickness in the order of 200 to

300 μ m, whereas a stationary anode target has a thickness of approximately 0.5 to 3mm. The position (focal point) of the revolving anode target struck by thermions released from the cathode is shiftable with revolution of the target. With the stationary anode target, this focal point does not shift so that the target itself must have a large heat capacity. For this reason, a stationary anode target of increased thickness is desired. It would be time-consuming and greatly impair manufacturing efficiency if a thick target is formed by depositing the anode target material by chemical vapor deposition on a flat end surface of the anode base. To secure a high manufacturing efficiency, according to this invention, a recess is formed in the end surface of the anode base for allowing the anode target material to be deposited therein effectively. That is, target material reaction gases supplied during a chemical vapor deposition process tend to remain in the recess formed in the end surface of the anode base. Consequently, the anode target material is deposited at a higher rate in the recess than in other flat regions, thereby forming the anode target in the recess efficiently.

The second reason is to facilitate a machining process after the anode target material is deposited on

the end surface of the anode base. When the anode target is formed by chemical vapor deposition in the recess formed in the end surface of the anode base, the anode target material is deposited in a thin layer also
5 in regions of the end surface other than the recess. Such thin target portions could peel off when subjected to a high temperature during use of the X-ray tube or during manufacture thereof, thereby causing malfunctioning of the X-ray tube. It is therefore necessary
10 to scrape off such thin target portions after the anode target material is deposited on the end surface of the anode base. According to this invention, the end surface of the anode base is polished with a polishing machine or the like to remove with ease the anode
15 target material deposited in the regions of the end surface other than the recess. At this time, the anode target proper formed in the recess is not scraped off in an excessive amount.

The third reason is to enhance heat conductivity
20 from the anode target to the anode base. Where the anode target is formed in the recess of the anode base, a large area of contact is secured between the anode target and the anode base to enhance heat conductivity, compared with the case of forming an anode target in
25 elevation on a flat end surface of the anode base.

According to this invention, the recess formed in the end surface of the anode base to have an upwardly diverging inner peripheral wall for the following reason.

5 If the inner peripheral wall of the recess extended perpendicular to the bottom surface or converged so as to overhang the bottom surface, the reaction gases would not flow in sufficient amounts to the corners of the bottom surface of the recess when depositing the
10 anode target material by chemical vapor deposition in the recess. As a result, the anode target material would not be deposited in the corners, tending to leave spaces (gaps) therein. Such gaps present between the anode target and anode base are detrimental to heat
15 conductivity, and could cause cracks in the anode target during use of the X-ray tube, or a concentration of electric fields, thereby lowering withstanding voltage. Further, during the chemical vapor deposition process, the anode target material begins to accumulate
20 in directions perpendicular to the bottom surface and inner peripheral wall of the recess. As the accumulation progresses, the anode target material extends vertically upward. Consequently, where the corners of the bottom surface of the recess have an acute angle,
25 an interference would occur in the vicinity of the

corners between portions of the anode target material growing perpendicular to the inner peripheral wall and bottom surface, respectively. This interference tends to cause turbulence in crystallization of the anode target formed adjacent the corners of the bottom surface of the recess. Such turbulence in crystallization results in cracks and peeling of the anode target.

According to this invention, therefore, the inner peripheral wall of the recess is shaped to diverge upward for allowing the anode target to be deposited in the recess. This configuration allows no gaps to be left between the anode target and anode base, whereby the anode target formed has an excellent crystal structure.

Preferably, the upwardly diverging inner peripheral wall has an inclination angle of at least 30 degrees but less than 90 degrees. It is still more advantageous if the inclination angle is in the range of 30 to 70 degrees. If the inclination angle were 90 degrees or larger, the corners of the bottom surface of the recess form an acute or near-acute angle to allow formation of gaps in the corners when the target material is deposited as noted above. If the inclination angle of the inner peripheral wall were less than 30 degrees, the anode target would be formed too thin

adjacent edges of the recess. Such thin peripheral portions of the target could easily be cracked or peeled off when an intense thermal load is applied thereto, or under a thermal stress due to a difference
5 in thermal expansion coefficient between the anode base (e.g. copper) and a metal of high melting point forming the anode target which occurs at a step of brazing glass-sealing covar (i.e. heating to 800 to 850°C) in manufacture of the X-ray tube.

10 It is preferred, according to this invention, that the anode base is formed of copper which has high heat conductivity, and that the anode target material is a metal of high melting point such as tungsten (W), molybdenum (Mo), an alloy of tungsten (W) and molybde-
15 num (Mo), an alloy of tungsten (W) and rhenium (Re), or an alloy of molybdenum (Mo) and rhenium (Re).

In another aspect of the invention, a method of manufacturing an anode for use in an X-ray tube is provided which comprises the steps of:

20 covering, with a masking material, an outer peripheral wall of an anode base with a recess formed in an end surface thereof and having an upwardly diverging inner peripheral wall;

depositing an anode target material by chemical
25 vapor deposition directly on the end surface; and

shaping the end surface by mechanically polishing the end surface where the anode target material is fixed, to remove the anode target from end surface regions other than the recess.

5 According to this method, the anode target material is deposited by chemical vapor deposition, with the outer peripheral wall of the anode base covered with a masking material. Thus, the outer peripheral wall of the anode base remains free from adhesion of the anode
10 target material, thereby to lighten the load of the subsequent machining process. After the anode target is deposited on the end surface of the anode base, the end surface is mechanically polished to remove unwanted portions of the anode target material, leaving the
15 anode target formed in the recess.

 In the above method, the masking material, preferably, comprises the same metallic material used for forming the anode base. When exposed to a hot atmosphere during chemical vapor deposition of the anode
20 target material, the masking material readily joins the outer peripheral wall of the anode base, leaving little or no gaps therebetween. This is effective to avoid adhesion of the anode target material to the outer peripheral wall of the anode base. Where the anode
25 base is formed of copper, for example, the masking

material may advantageously be copper foil.

Preferably, the recess is formed in the end surface before an opposite, proximal end of the anode base is machined, the proximal end being machined with
5 a surface of an anode target formed in the recess acting as a dimensional reference. According to this method, after the anode target is formed on the end surface of the anode base, the proximal end is machined using the surface of the anode target as a reference.
10 Thus, a length from the target surface to the proximal end may be established with high precision. If the proximal end of the anode base were machined before the anode target material is deposited, variations in the thickness of the anode target formed would affect the
15 precision of the length from the target surface to the proximal end. This dimensional precision is relevant to the precision of a focal position of the X-ray tube into which the anode is incorporated. Therefore, the method according to this invention which provides the
20 dimension from the target surface to the proximal end of the anode base with high precision is of practical advantage.

In a further aspect of the invention, a stationary anode X-ray tube is provided which comprises:
25 a cathode for releasing thermions;

a stationary anode for generating X rays when irradiated with the thermions; and

a vacuum envelope containing the cathode and the anode;

5 wherein the anode includes an anode base with a recess formed in an end surface thereof and having an upwardly diverging inner peripheral wall, and an anode target formed in the recess by directly fixing therein an anode target material by chemical vapor deposition.

10 BRIEF DESCRIPTION OF THE DRAWINGS

For the purpose of illustrating the invention, there are shown in the drawings several forms which are presently preferred, it being understood, however, that the invention is not limited to the precise arrange-
15 ments and instrumentalities shown.

Fig. 1 is a fragmentary sectional view of an X-ray tube anode manufactured by a conventional casting method;

Fig. 2 is a fragmentary sectional view of an X-ray
20 tube anode manufactured by a conventional brazing method;

Fig. 3 is a sectional view showing an outline of a stationary anode X-ray tube according to this invention;

Fig. 4 is a sectional view of an anode for the X-ray tube according to this invention;

Fig. 5 is a fragmentary sectional view of an anode for an X-ray tube in a different embodiment of the
5 invention;

Figs. 6A through 6F are explanatory views of an anode manufacturing method according to this invention;

Fig. 7 is an explanatory view of a CVD method employed in this invention; and

10 Fig. 8 is a view showing characteristics of a plane of interface between an anode target and an anode base provided by this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A preferred embodiment of this invention will be
15 described in detail hereinafter with reference to the drawings.

Referring to Fig. 3, a stationary anode X-ray tube includes a cathode 10 for releasing thermions, a stationary anode 20 opposed to the cathode 10 for
20 generating X rays when irradiated with the thermions, and a glass vacuum envelope 30 containing the cathode 10 and anode 20. The cathode 10 has a single or a plurality of filaments 11 which release thermions when electrified.

The anode 20, which forms the subject matter of this invention, has an approximately cylindrical anode base 21, and an anode target 22 directly deposited by chemical vapor deposition or CVD to an inclined end surface of the base 21 opposed to the cathode 10. The anode 20 is mounted in sealed condition, at a proximal end thereof remote from the inclined end surface where the target 22 is formed, in the vacuum envelope 30 through a metal element (e.g. covar element) 31 brazed in place. A cooling device 32 is attached to the proximal end of the anode 20. The cathode 10 has a cable 33 connected thereto for supplying power to the filament or filaments 11.

Details of the anode 20 will be described with reference to Fig. 4.

The anode base 21 is formed of a metal having high heat conductivity, such as copper. The anode base 21 defines in the inclined end surface a recess 23 which is circular in plan view. The target 22 is directly deposited by CVD inside the recess 23. The recess 23 has a depth in the order of 4mm which substantially corresponds to a thickness of target 22. The recess has an inner peripheral wall 23a diverging upward. The diverging wall 23a has an angle of inclination θ of 30 degrees or larger but less than 90 degrees, preferably

in the range of 30 to 70 degrees. As noted herein-
before, if the angle of inclination θ were 90 degrees
or larger, reaction gases supplied when the target 22
is formed by CVD would not flow smoothly to corners of
5 the bottom surface of recess 23. Gaps could thereby be
formed in the corners, or turbulence would tend to
occur in crystallization of portions of target 22
deposited adjacent the corners of the bottom surface of
recess 23. If the angle of inclination θ were less
10 than 30 degrees, peripheral portions of target 22 would
be formed too thin. Such thin peripheral portions of
target 22 could easily be cracked when an intense
thermal load is applied thereto during use of the X-ray
tube or when heat is applied at a brazing step in
15 manufacture of the X-ray tube.

The diverging inner peripheral wall 23a need not
define linear inclined surfaces as shown in Fig. 4, but
may define, for example, arcuate inclined surfaces 23a
as shown in Fig. 5.

20 A metal of high melting point is used as material
for the anode target 22 formed by CVD. A preferred
material is tungsten (W), molybdenum (Mo), an alloy of
tungsten (W) and molybdenum (Mo), an alloy of tungsten
(W) and rhenium (Re), or an alloy of molybdenum (Mo)
25 and rhenium (Re).

The proximal end of anode base 21 remote from the inclined end surface where the target 22 is formed defines a threaded hole 24 for connecting the cooling device 32 to the anode base 21 (see Fig. 3).

5 A method of manufacturing the anode 20 for the stationary anode X-ray tube having the above construction will be described next.

A cylindrical copper blank 21a for the anode base 21 as shown in Fig. 6A is machined into a shaped blank 10 21b as shown in Fig. 6B. The shaped blank 21b has the inclined end surface and recess 23 of anode base 21, but not the distal end of anode base 21 processed yet. In this example, the inner peripheral wall 23a of recess 23 has inclination angle θ set to 45 degrees.

15 Then, as shown in Fig. 6C, the outer peripheral wall of shaped blank 21b is covered with copper foil 25 acting as a masking material. The masking copper foil 25 may be shaped in varied ways according to quantities of production. For a small quantity, copper foil 25 20 may be shaped with a cutting tool with ease. For a large quantity, copper foil 25 may be press worked with dies. The copper foil 25 is bound with copper wire to be immovable. It is of course possible to clamp and fix the copper foil 25 in peripheral positions thereof 25 with repeatedly usable jigs. However, parts of the

target material and copper foil could adhere to the jigs to limit their life. It is advantageous to fix the copper foil with an inexpensive, disposable material such as copper wire.

5 It is preferable, as in this embodiment, that the masking material is the same metal as the anode base 21. However, stainless steel foil or fluororesin sheet may be used instead. Preferably, the copper foil 25 has a thickness of 30 to 100 μ m. If the copper foil 25
10 were less than 30 μ m thick, it would be difficult to separate the copper foil 25 from the anode base 21 after the target material is deposited by CVD. If the thickness of copper foil 25 exceeds 100 μ m, it would be difficult to wrap the copper foil 25 around the anode
15 base 21 with no gaps therebetween.

 After the outer peripheral wall of shaped blank 21b is covered with the copper foil 25, the shaped blank 21b is set, as shown in Fig. 7, in a reaction tube 41 of a CVD device. The reaction tube 41 has a
20 heater 42 mounted therein for supporting shaped blanks 21b, and reaction gas supply pipes 43a and 43b extending thereinto. Where the anode target is formed of tungsten, a mixture of tungsten fluoride (WF_6) gas and hydrogen (H_2) gas is supplied through each of the
25 reaction gas supply pipes 43a and 43b. Thus, tungsten

(W) is deposited on the inclined end surface of each shaped blank 21b by reducing tungsten fluoride with hydrogen in a hot atmosphere. The depositing conditions are, for example, that the temperature is 300 to 5 800°C, tungsten fluoride is supplied at a rate of 100 to 300cc/min. hydrogen at a rate of 300 to 1000cc/min. and the total pressure is 0.5 to 760 torr.

Since the recess 23 is formed in the inclined end surface of shaped blank 21b, a tungsten layer (anode 10 target) is deposited more quickly (i.e. thicker) in the recess 23 than in other regions of the inclined end surface. This is considered due to the fact that the reaction gases (WF_6 and H_2) supplied into the reaction tube 41 remain in the recess 23 for a relatively long 15 time. Further, since the inner peripheral wall of recess 23 is inclined (at 45 degrees), the tungsten layer is reliably deposited on the inner peripheral wall of recess 23 as well. The heat of CVD process causes the copper foil 25 covering the outer peripheral 20 surface of anode base 21 to fit tight on the anode base 21, eliminating gaps therebetween. Consequently, no tungsten layer is formed on the outer peripheral surface of anode base 21. Fig. 6D shows how the tungsten layer (anode target 22) has been deposited on 25 the inclined end surface of shaped blank 21b.

After formation of the tungsten layer, the shaped blank 21b is allowed to cool in the reaction tube 41 of CVD device 40 to a temperature at which the blank 21b may be removed from the reaction tube 41. A tungsten layer is formed in a certain amount also on the copper foil 25 in tight contact with the outer peripheral wall of shaped blank 21b. A difference in thermal expansion coefficient between the tungsten layer and shaped blank (copper) 21b results in a force acting in a direction to separate the copper foil 25 from the shaped blank 21b in the course of cooling after the layer formation. Thus, the copper foil 25 may be separated with facility after cooling. However, if the copper foil 25 is too thin, the foil 25 adheres firmly to the shaped blank 21b and would not readily peel off.

After the copper foil 25 is separated from the outer peripheral wall of shaped blank 21b, the inclined end surface of shaped blank 21b is mechanically polished as shown in Fig. 6E, to remove portions of the tungsten layer deposited in regions of the inclined end surface other than the recess 23. These portions of the tungsten layer are thin and, if left in such regions, would tend to crack or peel off when subjected to a high brazing temperature during an X-ray tube manufacturing process or under an intense thermal load

during use of the X-ray tube.

After the inclined end surface of shaped blank 21b is treated, the entirety of anode 20 is completed by machining the proximal end of shaped blank 21b (anode base 21), with the surface of anode target 22 in the recess 23 acting as a dimensional reference (see Fig. 6F). By machining the proximal end of anode base 21 at the final step as noted above, any variations in the thickness of anode target 22 may be absorbed and adjusted. This provides improvement in the precision of length L (Fig. 4) from the surface of target 22 to the proximal end, i.e. the precision of a focal position of the X-ray tube. If the proximal end of anode base 21 were machined before the anode target 22 is formed by CVD, the target 22 having a less thickness than a predetermined value would require an additional step of depositing the target material again to secure a standard length from the target surface to the proximal end.

Fig. 8 shows a photograph taken with a scanning electron microscope (SEM) of a plane of interface between tungsten (anode target 22) and copper (anode base 21) obtained by the above method; and results of elemental analysis (EPMA analysis) of the plane of interface. It is seen that the method of this

invention provides an excellent joint between tungsten and copper, with no gap in the plane of interface therebetween. Further, no impure elements are found in the plane of interface which would impair heat conductivity and long-term reliability.

To confirm validity of this invention, a test was conducted in which anodes obtained by the above CVD method and those prepared by the known casting method were sealed in X-ray tubes, respectively.

As test conditions, a long input was made (exposure to X rays for one minute) assuming X-ray fluoroscopy, and a comparison was made of maximum load inputs occurring when tungsten in the focal position of anode target 22 began to melt. The following results were obtained from the test:

	maximum load input
(1) X-ray tube A by CVD:	70kV - 6.2mA (434W)
X-ray tube B by CVD:	71kV - 6.0mA (426W)
X-ray tube C by CVD:	70kV - 5.8mA (406W)
(2) X-ray tube by casting:	72kV - 5.0mA (360W)

As seen from the above results, X-ray tubes A, B and C according to this invention showed an average of maximum load inputs at 422W. This confirms an improvement in maximum load input of about 17% over the conventional X-ray tube. A comparison was made also of

short-term maximum rating (condition for X-ray photography) for reference, but no difference was found between the two types of X-ray tubes.

As described above, a stationary anode X-ray tube
5 according to this invention allows increased input for
X-ray fluoroscopy to realize a correspondingly improved
radiographic image quality. Such a stationary anode
X-ray tube may be used also in operations including
large-dose fluoroscopy of 660W and 20sec. exposure, for
10 example, and simple DSA (Digital Subtraction
Angiography) requiring a similar, high output.

The present invention may be embodied in other
specific forms without departing from the spirit or
essential attributes thereof and, accordingly, refer-
15 ence should be made to the appended claims, rather than
to the foregoing specification, as indicating the scope
of the invention.



6. An anode as defined in claim 3, wherein said anode target material is an alloy of tungsten (W) and molybdenum (Mo).
7. An anode as defined in claim 3, wherein said anode target material is an alloy of tungsten (W) and rhenium (Re).
8. An anode as defined in claim 3, wherein said anode target material is an alloy of molybdenum (Mo) and rhenium (Re).
9. A method of manufacturing an anode for use in a stationary anode X-ray tube, comprising the steps of:
- 5 covering, with a masking material, an outer peripheral wall of an anode base with a recess formed in an end surface thereof and having an upwardly diverging inner peripheral wall;
- depositing an anode target material by chemical vapor deposition directly on said end surface; and
- shaping said end surface by mechanically polishing
- 10 said end surface where said anode target material is fixed, to remove said anode target from end surface regions other than said recess.



* C L M S *

What is claimed is:

1. An anode for use in a stationary anode X-ray tube, comprising:

an anode base with a recess formed in an end surface thereof and having an upwardly diverging inner peripheral wall; and

an anode target formed in said recess by directly fixing therein an anode target material by chemical vapor deposition.

2. An anode as defined in claim 1, wherein said upwardly diverging inner peripheral wall has an inclination angle of at least 30 degrees but less than 90 degrees.

3. An anode as defined in claim 1, wherein said anode base is formed of copper.

4. An anode as defined in claim 3, wherein said anode target material is tungsten (W).

5. An anode as defined in claim 3, wherein said anode target material is molybdenum (Mo).



10. A method as defined in claim 9, wherein said masking material comprises the same metallic material used for forming said anode base.
11. A method as defined in claim 10, wherein said anode base and said masking material are formed of copper.
12. A method as defined in claim 9, wherein said recess is formed in said end surface before an opposite, proximal end of said anode base is machined, said proximal end being machined with a surface of an anode target formed in said recess acting as a dimensional reference.
13. A stationary anode X-ray tube comprising:
a cathode for releasing thermions;
a stationary anode for generating X rays when irradiated with said thermions; and
a vacuum envelope containing said cathode and said anode;
wherein said anode includes an anode base with a recess formed in an end surface thereof and having an upwardly diverging inner peripheral wall, and an anode target formed in said recess by directly fixing therein

This Sheet Has Been Replaced



HEET HAS BEEN
REPLACED

27



* C L M S *

an anode target material by chemical vapor deposition.



ANODE FOR AN X-RAY TUBE, A METHOD OF MANUFACTURING THE
ANODE, AND A STATIONARY ANODE X-RAY TUBE

ABSTRACT OF THE DISCLOSURE

This invention relates to an anode for use in an
X-ray tube and a method of manufacturing the anode, and
to a stationary anode X-ray tube. An anode base formed
5 of copper or the like includes a recess formed in an
end surface thereof and having an upwardly diverging
inner peripheral wall. An anode target material such
as tungsten is directly deposited in the recess by
chemical vapor deposition.

Fig.1 (PRIOR ART)

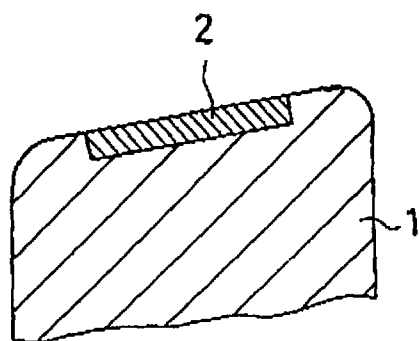


Fig.2 (PRIOR ART)

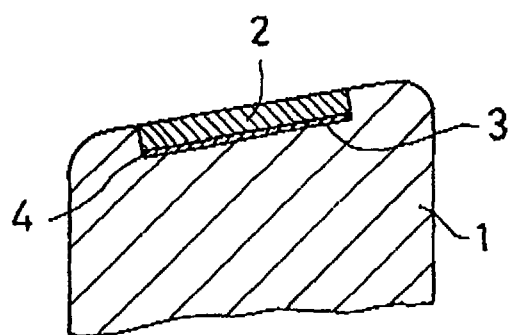


Fig. 3

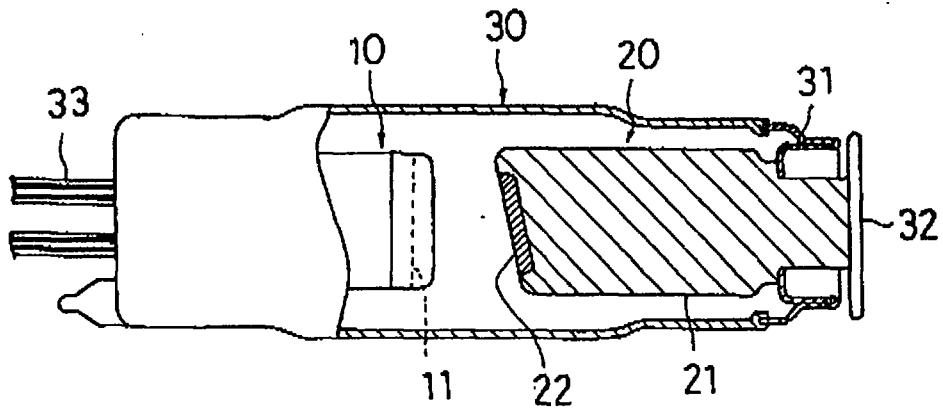


Fig. 4

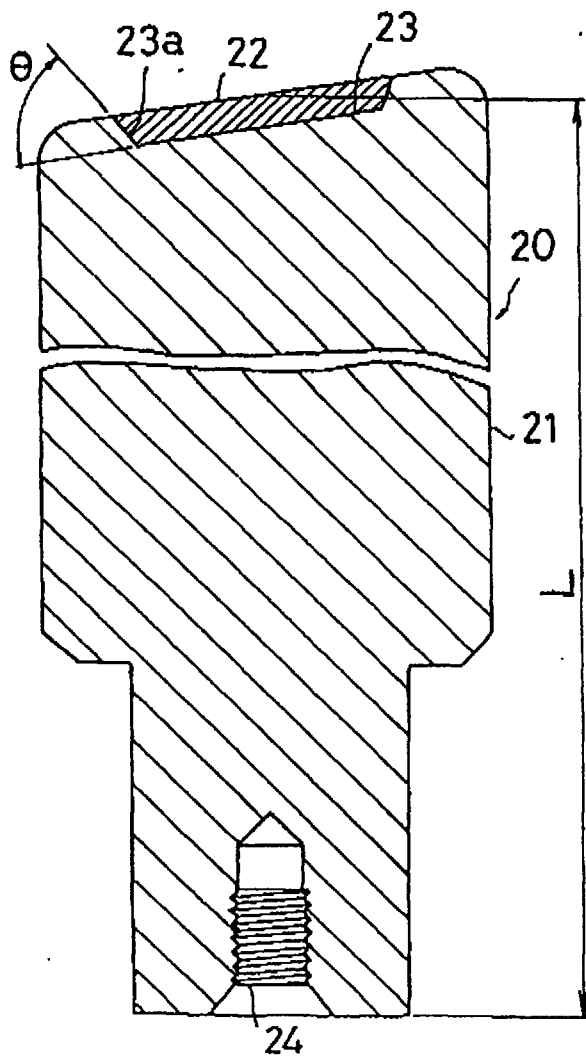


Fig. 5

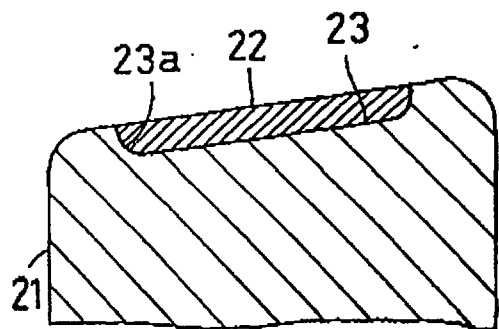


Fig 6A

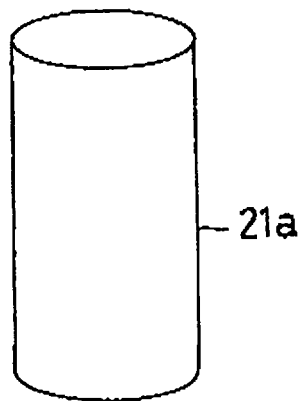


Fig 6D

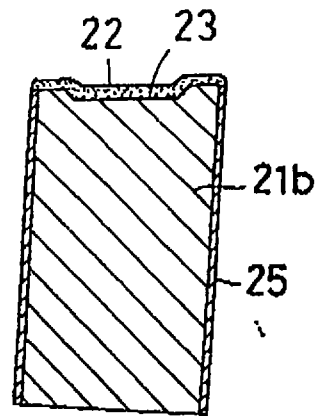


Fig. 6B

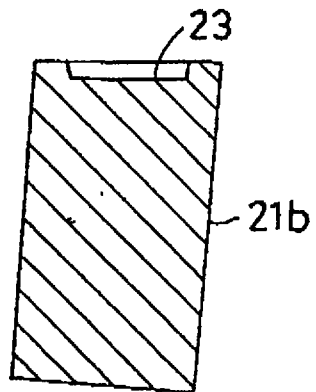


Fig. 6E

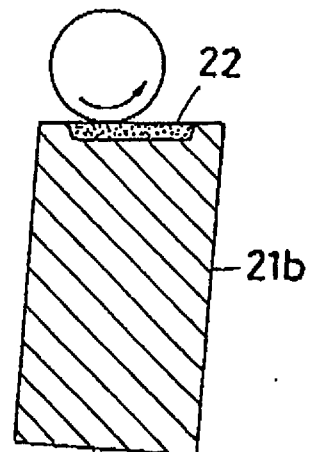


Fig. 6C

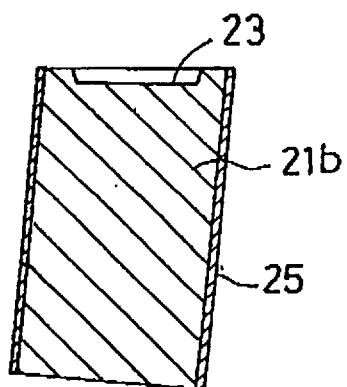


Fig. 6F

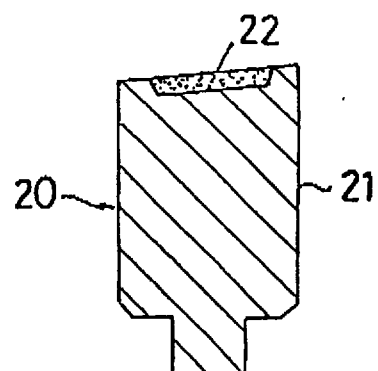


Fig. 7

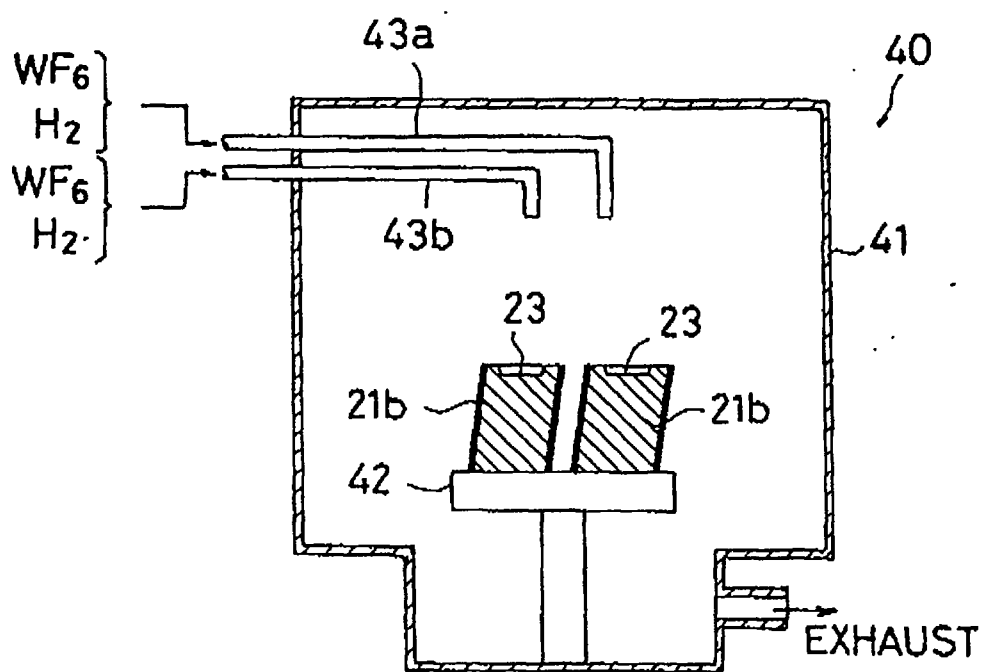
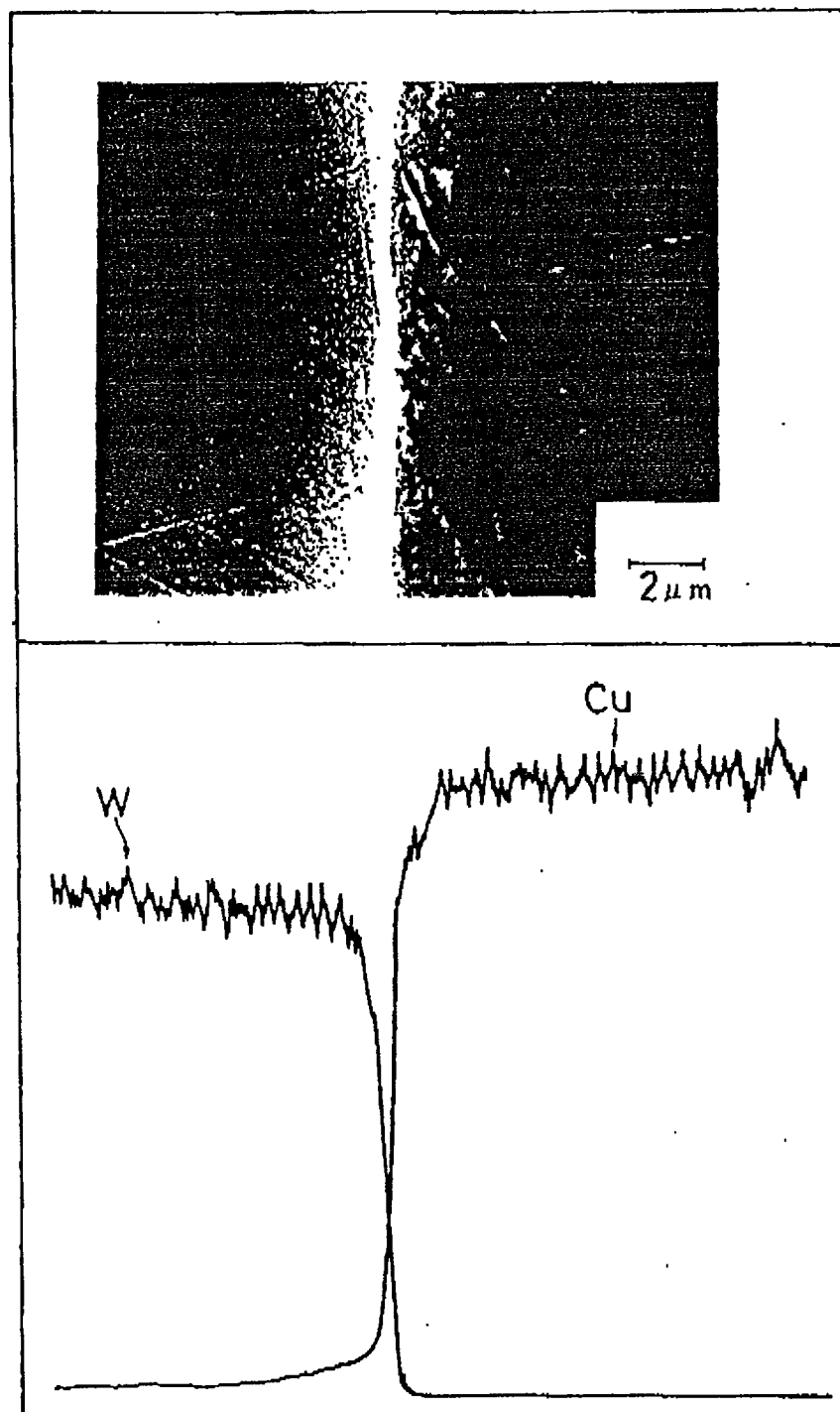


Fig. 8



ANODE FOR AN X-RAY TUBE, A METHOD OF MANUFACTURING THE
ANODE, AND A STATIONARY ANODE X-RAY TUBE

ABSTRACT OF THE DISCLOSURE

This invention relates to an anode for use in an
X-ray tube and a method of manufacturing the anode, and
to a stationary anode X-ray tube. An anode base formed
5 of copper or the like includes a recess formed in an
end surface thereof and having an upwardly diverging
inner peripheral wall. An anode target material such
as tungsten is directly deposited in the recess by
chemical vapor deposition.

Figure 4



What is claimed is:

1. ~~An anode for use in a stationary anode X-ray tube,~~
comprising:

an anode base with a recess formed in an end
surface thereof and having an upwardly diverging inner
5 peripheral wall; and

an anode target formed in said recess by directly
fixing therein an anode target material by chemical
vapor deposition.

2. An anode as defined in claim 1, wherein said
upwardly diverging inner peripheral wall has an incli-
nation angle of at least 30 degrees but less than 90
degrees.

3. An anode as defined in claim 1, wherein said anode
base is formed of copper.

4. An anode as defined in claim 3, wherein said anode
target material is tungsten (W).

5. An anode as defined in claim 3, wherein said anode
~~target material is molybdenum (Mo).~~



6. ~~An anode as defined in claim 3, wherein said anode target material is an alloy of tungsten (W) and molybdenum (Mo).~~

7. An anode as defined in claim 3, wherein said anode target material is an alloy of tungsten (W) and rhenium (Re).

8. An anode as defined in claim 3, wherein said anode target material is an alloy of molybdenum (Mo) and ~~rhenium (Re).~~

9. A method of manufacturing an anode for use in a stationary anode X-ray tube, comprising the steps of:

covering, with a masking material, an outer peripheral wall of an anode base with a recess formed
5 in an end surface thereof and having an upwardly diverging inner peripheral wall;

depositing an anode target material by chemical vapor deposition directly on said end surface; and

shaping said end surface by mechanically polishing
10 said end surface where said anode target material is fixed, to remove said anode target from end surface regions other than said recess.

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10. A method as defined in claim 9, wherein said masking material comprises the same metallic material used for forming said anode base.

11. A method as defined in claim 10, wherein said anode base and said masking material are formed of copper.

12. A method as defined in claim 9, wherein said recess is formed in said end surface before an opposite, proximal end of said anode base is machined, said proximal end being machined with a surface of an anode target formed in said recess acting as a dimensional reference.

~~13. A stationary anode X-ray tube comprising:~~

~~a cathode for releasing thermions;~~

~~a stationary anode for generating X rays when irradiated with said thermions; and~~

~~5 a vacuum envelope containing said cathode and said anode;~~

~~wherein said anode includes an anode base with a recess formed in an end surface thereof and having an upwardly diverging inner peripheral wall, and an anode target formed in said recess by directly fixing therein~~



REPLACEMENT SHEET

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~~an anode target material by chemical vapor deposition.~~