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Friedel

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[54] **X-RAY TUBE WITH ROTARY ANODES**

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[51] **Int. Cl.**..**H01j 35/10**
[58] **Field of Search**......................313/330, 352, 355

[56] **References Cited**

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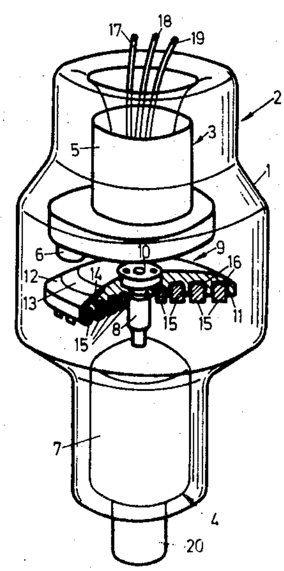
[57] **ABSTRACT**

An X-ray tube has a rotary anode which is a compound body with parts of heavy metal and graphite, the focal point path lying upon the heavy metal. The invention is particularly characterized by the provision of at least one graphite part at the heavy metal part outside of the focal point path.

19 Claims, 6 Drawing Figures



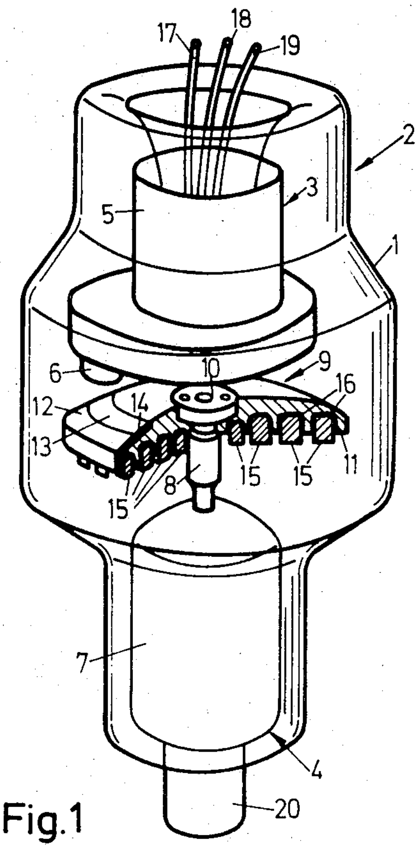


Fig.1

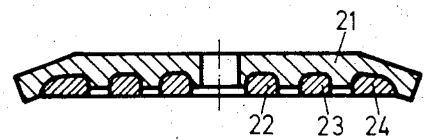


Fig. 2

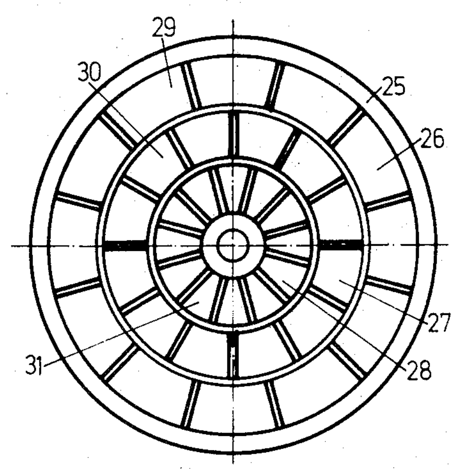


Fig. 3

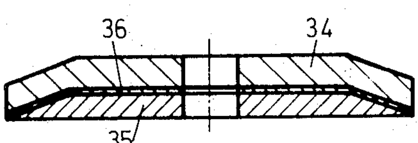
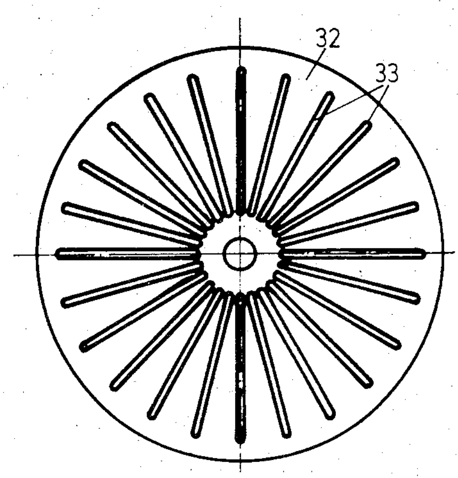


Fig.5



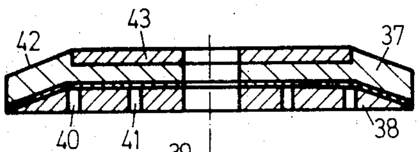


Fig. 6

Fig.4

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X-RAY TUBE WITH ROTARY ANODES

DESCRIPTION OF THE INVENTION

This invention relates to an X-ray tube with rotary anodes, the anode being a compound body with parts of heavy metal and graphite, the focal point path lying upon the heavy metal.

X-ray tubes with such anodes are used due to the high specific heat and the good ray emitting capacity of graphite in order to produce higher loads.

Anodes containing graphite and now used as rotary anodes for X-ray tubes consist of a graphite disc the surface of which at least in the area of the focal point path is coated with a layer of heavy metal. Such layers are produced, for example, by steaming, spraying or by pyrolytic decomposition of compounds. The layers must be thin in order to be able to operate effectively and to utilize the technological data. Such layers have, however, the drawback that they are destroyed when tungsten is used, forming a carbide. Furthermore, carbide layers are brittle and have bad heat conductivity, so that they are not adequate for the high heat exchange requirements of modern high output X-ray tubes. On the other hand, graphite has the drawback that it is difficult to eliminate gas from the large graphite volume due to its porosity. There is the danger that the anode will develop gas during subsequent operation. On the other hand, graphite can easily evaporate in case of high voltage impacts or small graphite parts can be torn off in high electrical field, as the result of which arc-like discharges are produced causing disturbance in cathode emission and finally destroying the X-ray tube. Furthermore, the mechanical strain upon graphite is very high due to revolving speeds up to and over 10,000 per min. and accelerations of 200 to 300 revolutions per sec^2. When graphite is selected it is necessary above all that it should have good strength. This means, however, that it is necessary to accept worse thermic properties and worse elasticity.

An object of the present invention is to eliminate these drawbacks of prior art constructions.

Other objects will become apparent in the course of the following specification.

In the accomplishment of the objectives of the present invention it was found desirable to make the compound body out of a disc-shaped heavy metal part wherein the graphite parts are applied outside of the focal point path. Thus an anode is produced, the carrying structure of which consists of a disc of heavy metal upon which graphite parts are provided which absorb and emit heat received by the plate from the focal point path. Then the anode is highly loaded for a short time period, since the heat transfer from the focal point path takes place faster due to high heat conductivity. On the other hand, there is also good continuous load capacity, since heat can be removed permanently from the graphite parts due to high heat and radiation capacity.

As compared to prior art X-ray tubes the present invention attains substantially the following advantages:

1. The short time load capacity corresponds at least to those of the usual heavy metal plates.

2. The long term load capacity is improved due to the additional heat capacity and radiation of graphite. Heat radiation can also exceed that of plates consisting solely of graphite due to different arrangement possibilities of the graphite parts and the heat conductivity through the metal.

3. The support of the plate consists of heavy metal so that when graphite is selected and its properties are considered it is not necessary to consider its strength.

4. The construction of the present invention provides a larger graphite surface relatively to volume than is the case in known graphite plates. This improves not only radiation but also degassing.

5. Graphite parts can be applied to the side of the anode plate which is away from the cathode, so that these parts are located outside of the direct high voltage field extending between the anode and the cathode.

In accordance with an embodiment of the present invention which is preferred due to its high efficiency, the anode consists of a heavy metal plate shaped in a manner known per se and consisting of molybdenum to which has been alloyed 5 percent tungsten, the plate having along the focal point path a covering layer of tungsten and 10 percent rhenium. Bore holes having a diameter of 5 to 35 mm. are provided from the lower side in this plate, their depth being about 5 mm. in case of a plate thickness of 10mm. It is also possible to use diameters which are smaller than 5mm., but then increased operational effort is necessary as related to effectiveness which is also increased. The upper limit of the size of the diameter of the bore holes and their depth is provided by the size of the anode plate, its diameter and thickness. Graphite bodies are soldered into the bore holes; they fill the holes to the greater extent and their top can coincide with the plate surface or, depending upon space conditions, they can project above the plate surface to the extent of 25 mm. or more. The extending part can have a different shape than that of the bore hole, it can be conical, etc. The extending parts can be also varied in length, for example, they can be shorter at the edges of the plate than at its middle; such variations can facilitate ray emission and be useful and necessary for geometrical reasons.

Various high melting metals or their mixtures, preferably zirconium-molybdenum or zirconium-tungsten-eutectic are suitable as solder. Good soldering can be also produced with a autectic of molybdenum and molybdenum-carbide. The soldering can take place in a known manner by adding a powder mixture corresponding to the desired composition to the part to be soldered and providing the heating. When a molybdenum body is used, the molybedenum-molybdenum carbide-eutectic solder can be also produced without a special solder. It is merely necessary to place the graphite parts into the desired position and then heat to about 2200°C. At this temperature soldered eutectic is formed at the places of contact.

When an X-ray tube is operated high anode temperatures and high differences in temperature take place in the anode. Even if the heavy metal and the used graphite had the same thermic coefficients of expansion, — which, however, is never the case for the wide temperature range from about 0°C to 2500°C, — thermic tensions occur in the anode due to different temperatures. This results in great danger to solder connections between heavy metal and graphite primarily due to shearing and traction tensions. Graphite itself has only small resistance to shearing and traction, but good pressure resistance. These difficulties are also eliminated by the present invention. The fixing of the graphite part takes place, for example, in molybdenum at the solidification temperature of the solder being used. Since molybdenum has a greater thermic expansion coefficient than graphite, parts of graphite are firmly held under pressure after further cooling (co-called shrinking process). Since the soldering surface is spaced from the location where heat of the focal point path is produced, the melting temperature of the solder is not reached in operation. Thus no shearing and traction tensions occur at the soldering surface, but only pressure tensions, so that the strength of the connection is very good. In addition, the solder improves the heat contact and thus heat transmission from heavy metal to graphite.

When proper composition is used, the diffusion of carbon into the heavy metal is also prevented. Solder suitable in this connection may be zirconium carbide, tantalum carbide, hafmium carbide, etc. When *Zr* or H*f* are used a diffusion preventing layer is produced by itself at the contacting surface with carbon (graphite, etc.) during the heating, i.e., soldering.

It is possible to avoid the boring of a large number of holes if grooves are bored concentriclaly about the axis of rotation upon the underside of the metal plate, these grooves being filled with suitable graphite rings. These rings can be radially divided to improve the soldering connection. A construction having radial cooling ribs is produced by applying strip-shaped graphite parts with their narrow sides in radial direction to the underside of the plate; these parts can be also divided.

When sufficiently balanced thermic expansion properties have been provided, it is possible to solder a graphite disc having a thickness of about 1 mm. to 10 mm. to the underside of the plate, so that the entire surface of the plate will be covered. The reliability of the solder connection in case of thermic alternate stresses is increased by providing the graphite plate with radial and/or concentric recesses. It is also possible to provide structural parts increasing the surface, such as ribs, etc. In case of X-ray tubes wherein only small amounts of stray electrodes, etc. strike the surface directed toward the cathode and which do not have to be operated with very high voltages, the upper parts of the anodes can be additionally provided with graphite parts to further increase heat emission.

The invention will appear more clearly from the following detailed description when taken in connection with the accompanying drawing showing by way of example only, preferred embodiments of the inventive idea.

In the drawing:

FIG. 1 is a perspective view of an X-ray tube the anode of which has been broken off to show graphite parts soldered in bore holes upon its underside.

FIG. 2 is a section through an anode the underside of which contains graphite rings in concentrical grooves.

FIG. 3 is a bottom view of an anode wherein the rings of FIG. 2 are provided with radial interruptions.

FIG. 4 is a bottom view of an anode having radially applied strip-like cooling ribs of graphite.

FIG. 5 is a section through an anode the underside of which is completely covered by a graphite part.

FIG. 6 is a section through an anode which additionally is also provided with a graphite part upon its upper side.

FIG. 1 shows a glass bulb **1** of a rotary anode X-ray tube **2**. The bulb **1** has at one end the cathode **3** and at the other end the anode **4**. The cathode **3** consists of a cover **5** which contains in a lug **6** the actual glow cathode (not shown) of standard construction. The anode **4** includes in a manner which is also known, the rotor **7** carrying by its axle **8** the actual compound anode **9** which is held firmly by a screw **10**. The anode **9** consists of a metal body **11** of an alloy of molybdenum and 5 percent tungsten. The two focal point paths **12** and **13** extend downwardly at different inclinations relatively to the vertical line of the axle **8** and are located upon a coating **14** consisting of an alloy of tungsten and 10 percent rhenium, the coating having a thickness of 1 mm.

The underside of the metal part **11** which has a thickness of 10 millimeters is provided with bore holes having a depth of 4 millimeters in which graphite parts **15** are soldered. The solder is the eutectic obtained from molybdenum and zirconium. The actual solder is indicated in the drawing by thicker lines enclosing the bore holes and is designated by the numeral **16**.

X-rays are produced in a known manner by providing high voltage between one of the conduits **17**, **18** and **19** and the anode stem **20** and by providing heating voltage between one of the conduits **17** and **18** and the conduit **19** for the glow cathodes located in the lug **6**. Electrons proceeding from the glow cathode then strike one or both of the focal point paths and produce X-rays. As is known, a great deal of heat appears as a by-product. This heat is conducted in the metal part **11**, accumulated in the graphite parts **15** and then removed as rays.

FIG. 2 shows a plate **21** consisting of molybdenum the underside of which is provided with annular grooves extending concentrically to the axis of rotation. Graphite rings **22**, **23** and **24** are soldered into these grooves. As in the construction of FIG. **1**, in this construction also heat transmission takes place through the graphite parts **22**, **23** and **24**.

This construction is again changed into that of FIG. **3** showing an anode plate **25** consisting of molybdenum and provided with annular grooves **26**, **27** and **28**. Sector-shaped parts of graphite rings are so introduced into these grooves that radial interruptions are provided, which are spaced from each other in the individual rings. The graphite parts of the outer groove **26** are indicated by the numeral **29** in the drawing, those of the middle groove **27** with the numeral **30** and those of the inner groove **28** with the numeral **31**. The soldering takes place by heating to a temperature of about 2200°C. A mixture of molybdenum and molybdenum-carbide power is additionally introduced between the ring pieces.

FIG. 4 shows a plate **32** of a rotary anode, the plate having a thickness of 10 millimeters. Strip-like graphite parts **33** are provided on the underside of the plate **32** as radial cooling ribs. For this purpose corresponding radial grooves are milled wiich are three to 5 millimeters deep, so that the graphite parts **33** having a width of 10 millimeters can be soldered into these grooves and still project outwardly to the extent of 10 to 20 millimeters. This construction also has good capacity for heat absorption and heat reflection.

FIG. 5 shows an anode molybdenum plate **34** which is 8 millimeters thick and at the underside of which a graphite body **35** having a thickness of 6 millimeters is soldered by a soldering layer **36** consisting of *Zr*/*Mo*.

FIG. 6 shows an anode plate **37** to the underside of which has been soldered a graphite body **38** of tungsten. Furthermore, the plate **37** has upon its upper side a surface limited by the inner edge of the focal point path **42** which is deepened and which contains a graphite body **43** soldered therein. This construction provides a better heat transmission upwardly. Furthermore heat capacity is enlarged by an increase of graphite bodies.

I claim:

1. In an X-ray tube, a rotary anode having an axle, a rotary plate of heavy metal carried by said axle and receiving the focal point path of the X-ray tube, and at least one graphite part applied to said heavy metal plate outside of the focal point path.

2. An X-ray tube in accordance with claim 1, wherein graphite parts are applied only to the underside of the part consisting of heavy metal.

3. An X-ray tube in accordance with claim 1, wherein the graphite parts are soldered by a layer of soldering.

4. An X-ray tube in accordance with claim 1, wherein the heavy metal part has bore holes, several graphite parts having the shape of plugs being fixed in said bore holes.

5. An X-ray tube in accordance with claim 4, wherein the bore holes have rounded ends.

6. An X-ray tube in accordance with claim 1, wherein the heavy metal part has annular grooves extending concentrically to its rotary axis, the graphite part consisting of graphite rings inserted into said grooves.

7. An X-ray tube in accordance with claim 6, wherein said graphite rings are divided radially into segments.

8. An X-ray tube in accordance with claim 1, wherein the graphite part consists of strips mounted as radial cooling ribs upon the underside of the heavy metal part.

9. An X-ray tube in accordance with claim 1, wherein the entire underside of the heavy metal part is covered by the graphite part consisting of a plate.

10. An X-ray tube in accordance with claim 2, wherein graphite parts are additionally applied to the upper side of the part consisting of heavy metal.

11. An X-ray tube in accordance with claim 9, wherein the graphite parts have concentrical and/or radial cutouts.

12. An X-ray tube in accordance with claim 1, wherein the heavy metal part has the shape of a rotary anode plate.

13. An X-ray tube in accordance with claim 1, wherein the heavy metal consists of molybdenum.

14. An X-ray tube in accordance with claim 3, wherein the layer of soldering consists of the eutectic of zirconium and tungsten.

15. An X-ray tube in accordance with claim 3, wherein the layer of soldering consists of an alloy containing 70 percent zirconium and 30 percent molybdenum.

16. An X-ray tube in accordance with claim 3, wherein the layer of soldering consists of the eutectic of molybdenum and molybdenum carbide.

17. An X-ray tube in accordance with claim 1, wherein the heavy metal part consists of molybdenum and wherein the graphite parts are fixed to the heavy part by heating to a temperature of 2200°C.

18. An X-ray tube in accordance with claim 3, wherein the surfaces of the graphite parts which are to be soldered are initially coated with a layer of zirconium carbide, tantalum carbide or hafmium carbide.

19. An X-ray tube in accordance with claim 3, wherein the soldering consists of zirconium or hafmium.

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