

[54] X-RAY TUBE TARGET

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[58] Field of Search 313/60, 330

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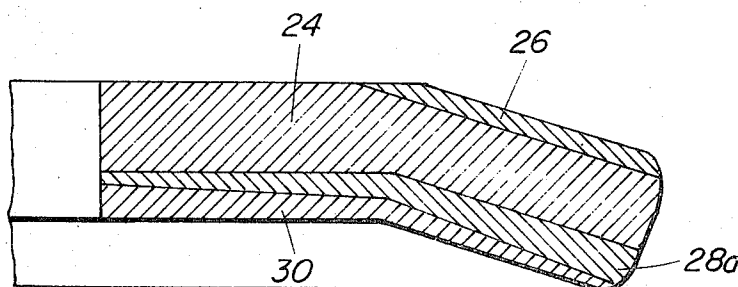
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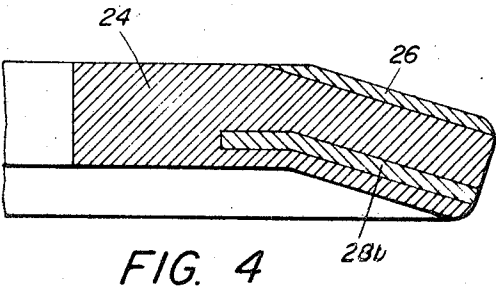
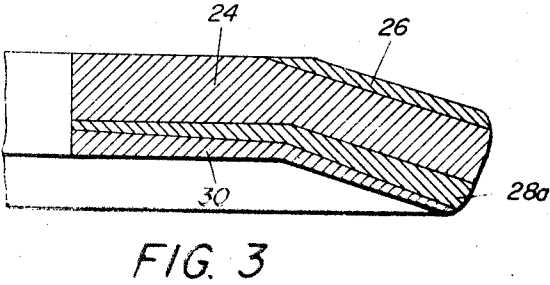
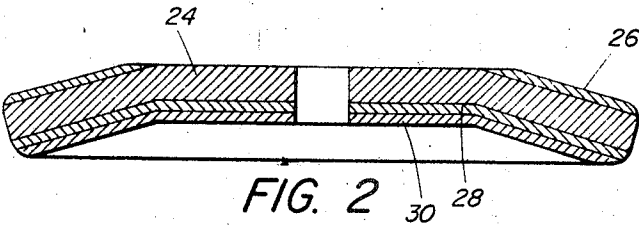
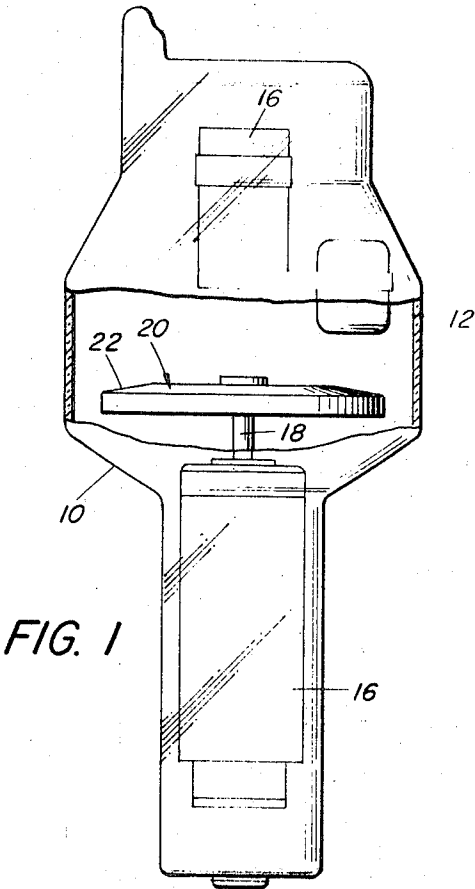
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[57] ABSTRACT

A target for anodes of X-ray tubes, particularly rotating anodes, having a compensated bimetallic structure which comprises a base matrix carrying coatings of selected material on both opposed surfaces for resisting distortion caused by high thermal energies.

11 Claims, 4 Drawing Figures





X-RAY TUBE TARGET

BACKGROUND OF THE INVENTION

In X-ray tubes, a principal problem relates to the dissipation from the anode of heat which is produced by electron bombardment thereof. This is particularly true of rotating anodes where cooling takes place principally by radiation.

Tungsten has been well known as a material which efficiently produces X-ray when bombarded by electrons. However, when anodes are made of so-called "pure" tungsten, at high thermal energies radial cracking and crystalline separation or flaking commonly occur, probably because surface expansion occurs more quickly and is much greater than that of the interior of the target body.

Other high atomic number materials such as, for example, molybdenum and graphite are also well suited for use as target materials because of their relatively light weight and fairly good thermal capacities. Such targets in the past have generally been coated in the area of the focal spot with a layer of tungsten or combination of tungsten and rhenium. This has resulted in some reduction in cracking and flaking. However, undesirable characteristics still occur to a very undesirable extent and are commonly evidenced as warping or distortion of the layer, in addition to cracking.

The heat developed by an anode will vary considerably. For example, a 0.3 mm square projected focal spot on a 10° target when bombarded with electrons for 0.01 second will develop heat of as much as 8-12 kw. A 2 mm square projected focal spot on a 10° target, bombarded for 0.01 second, will develop more than 100 kw of heat. Such heat will cause the target to distort or bend in a direction toward the electron source. Since the focal area of the target is inclined at a selected angle, such as 10°, such bending will produce a resultant decrease in the size of the projected focal spot, sometimes to the point where the projected focal spot becomes nonexistent, resulting in an X-ray tube which will not emit any useful X-radiation.

Many attempts have been made to reduce the heat problem by increase of actual surface area or by coating the surface of the anode with a material having high thermal emissivity. Schram, in U. S. Pat. No. 2,863,083, for example, teaches a molybdenum, graphite or boron target coated on its focal surface with a layer of tungsten and then additionally coated with a layer of rhenium which may extend over just the focal surface or over both the sides and edges of the target. Schram attempts to create high thermal emissivity.

British specification No. 616,490 teaches the use of a molybdenum disc having a thin tungsten layer in its bombarded surface. Ochsner et al in U. S. Pat. No. 3,112,185 discloses an anode for electron discharge devices, which anode comprises a five-layer structure which is intended to prevent thermal deflection characteristics by virtue of the fact that the composite structure is an asymmetrical body comprised of material having different thermal expansion, such materials being copper coated on opposite surfaces with steel overlaid with aluminum.

Neither Schram nor the British invention has proved to be successful, while the Ochsner et al. materials cannot be used in the fabrication of rotating X-ray targets for many reasons.

SUMMARY OF THE INVENTION

In accordance with the objectives of this invention, there is provided an X-ray tube target which is so constructed as to eliminate warping, bending or distortion prevalent in targets having high thermal emissivity coatings only on the focal side of the target. This is achieved by the provision of a compensated bimetallic structure which embodies a deposit or cladding of the high thermal emissivity coating material on both the focal side and the opposite side of the target, which coating is deposited directly upon the base substrate material to a thickness greater than 0.010 inch, since thinner coatings will provide a structure wherein the temperature differential between the substrate and the coating is too small, leading to substrate melting beneath the focal spot. Coatings up to about 0.050 inch are satisfactory, coatings of greater thickness being fabricatable but impractical due to unnecessary use of expensive materials and the fact that the coating will be so thick as to nullify the benefit of the light weight, high heat capacity substrate.

The base substrate conveniently may be molybdenum coated on both surfaces with tungsten or tungsten-rhenium alloy. The substrate-coating thickness ratio will preferably be about 4-7 to 1.

Additionally, a fourth layer of machinable material is disposed upon the surface coating which is disposed on the side of the target away from the electron source. Such an additional layer has been found to prevent the weakening of the adjacent rigidizing layer by loss of strength induced by mechanically treating the layer during target balancing procedures.

Since the greatest concentration of heat is developed in the marginal or focal area of the target, the present invention is directed particularly to the provision of means in this area for preventing distortion by heat. Therefore, in one embodiment of the invention a ring of rigidizing material is embedded within the base material of the target in the focal area thereof.

In another embodiment, the layer of rigidizing material is made to be substantially thicker opposite the focal area than the remainder thereof.

With a structure as set forth herein, the compensated bimetallic feature results in considerably less warpage, compared to prior art types of target structures, and permits X-ray tubes to be operated at higher thermal loadings without damage.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an elevational view of an X-ray tube having a rotating target embodying the invention;

FIG. 2 is a sectional view through a target embodying this invention; and

FIGS. 3 and 4 are fragmentary sectional views of a target embodying two further embodiments of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring more particularly to the drawing, there is shown in FIG. 1, by way of example, one type of X-ray generator tube having a rotatable anode. The glass envelope 10, which contains a high vacuum, houses the cathode 12 which is mounted on a suitable cathode support structure 14 sealed into one end of the envelope. A rotor 16 is sealed into the opposite end of the

envelope and has extending inwardly from it an operating shaft 18 on the inner end of which is a transversely extending disc-like anode target 20. The cathode 12 is offset with respect to the center of rotation of shaft 18 and target 20 so as to direct electrons onto an inclined annular surface 22 of the target. In the normal and well-known manner, the electrons from cathode 12 are focussed onto a small area of the target, this area being of predetermined size, such as 0.3 mm square projected, 2 mm square projected, or other square, rectangular or other configuration and size as desired.

The anode and cathode structures are connected to suitable sources of potential, as is conventional, to produce a stream of electrons which impinge upon the focal spot for a predetermined pulse duration such as 0.01 second, for example. During this process the anode target 20 is rotated at a high speed. Thus, the focal spot traverses an annular track on the inclined surface 22 during the pulse duration. Impingement of electrons on the target surface creates considerable heat not only on the surface of the target but within the body thereof, as is well known, particularly in the portion opposite the focal track.

The target 20 comprises a circular disc 24 of molybdenum or graphite (FIG. 2) which is critically balanced to rotate about its geometric center, and is coated on its surface adjacent the cathode 12 with a layer 26 of tungsten or tungsten-rhenium alloy. However, the particularly important feature of this invention resides in the fact that a compensated bimetallic structure is achieved by also providing a layer 28 of the same tungsten or tungsten-rhenium alloy or other rigidizing material on the back surface of the target; that is, the surface opposite the surface which is subjected to electron bombardment.

Layers 26 and 28 must be at least 0.010 inch thick but, for practicality, should not exceed 0.050 inch maximum thickness. These layers may be pure tungsten or may comprise an alloy comprising tungsten or rhenium, in which case the tungsten may comprise about 90 percent and rhenium about 10 percent. The selected coating material or materials are ground, mixed, pressed and sintered to the molybdenum surfaces by conventional, well-known processes.

It has been found that when a molybdenum base 24 is provided with only a single layer 26, the high thermal stresses to which the target is subjected during processing and operation of an X-ray tube will cause considerable warping and rippling of the layer 26, particularly in the focal track area. The molybdenum base material deforms at high temperature, but resists complete reverse deformation upon cooling, resulting in a lessening of the target angle, that is, the angle of inclination of inclined surface 22.

It is known that molybdenum has an expansion coefficient of about 49×10^{-7} inch per inch per degree Centigrade. Tungsten expands only about 26×10^{-7} inch per inch per degree Centigrade. Therefore, it will be apparent that when the anode target 20 is heated, the molybdenum disc 24 will expand and, in doing so, will tend to flatten from its slightly cup-shaped configuration. This will not only alter the angle of the inclined surface 22, that is, alter the actual spacing between surface 22 and the cathode 12, resulting in change in focal spot size, but will also produce slight distortions such as convolutions or ripples in the coating 26.

In accordance with this invention the compensated bimetallic effect created by the second layer 28 produces a resistance to such deformation of the molybdenum disc 24 and consequently also reduces the tendency of the layer 26 to warp or ripple. Cracks and crazing or flaking are also less common, resulting in more efficient X-ray generation.

It is, of course, necessary that the rigidizing layer 28 be a material which has a substantially lower thermal expansion coefficient than the base material 24, but it should also be a material which may be satisfactorily used in X-ray tubes without substantially increasing the weight of the target.

In FIG. 2, the layer 28 is shown to be a layer of substantially uniform thickness extending across the entire lower surface of the disc 24.

In FIG. 3, the layer 28a is shown to be substantially thicker in the region of the focal area or the marginal area of the target, than in the interior portions thereof. For this purpose the layer is made to taper and thicken progressively outwardly from the center.

In FIG. 4 the rigidizing layer 28b is made in the form of a ring which is imbedded within the material of disc 24 at a level between the two opposed surfaces of the inclined focal area. Thus, the rigidization is confined to the area of the target where the greatest buildup of heat occurs.

In further accordance with this invention, there is provided an additional layer 30 on the back or bottom surface of the target as shown in FIGS. 2 and 3. Layer 30 overlies layer 28 and is preferably deposited or formed as a relatively uniformly thick layer. Layer 30 is of a metal having easy mechanical workability and may be molybdenum or graphite, for example, similar to the material of the base disc 24. It has been found that when the rigidizing layer 28 was abraded or otherwise mechanically treated during the balancing of the target, it sometimes became weakened sufficiently to lose its strengthening or distortion-preventing affect upon the disc. The added layer 30 therefore allows the rigidizing layer 28 to perform adequately while providing in itself a means whereby the target may be balanced.

From the foregoing it will be apparent that all of the objectives of this invention have been achieved by the structure shown and described. Other objectives and advantages of the invention will become apparent to those skilled in the art. Therefore, the structures shown and described are to be interpreted as illustrative.

I claim:

1. An X-ray tube having an electron-emitting cathode and an anode positioned in the path of electrons from the cathode, said anode comprising a rotatable shaft, and a disclike target on the shaft and rotatable therewith, the target being disclike in shape and having a selected portion disposed to rotate through the path of the electrons, said target comprising a substrate having a known coefficient of thermal expansion and having on both opposed surfaces layers of material which has a higher coefficient of thermal expansion than the material of the substrate, and a metallic coating overlying the layer on the side of the target remote from the cathode.

2. An X-ray tube as set forth in claim 1 wherein said substrate is molybdenum and said layers are a metal selected from the group consisting of tungsten and tungsten-rhenium alloy.

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3. An X-ray tube as set forth in claim 2 wherein said metallic coating is molybdenum.
4. An X-ray tube as set forth in claim 2 wherein said metallic coating is graphite.
5. An X-ray tube as set forth in claim 1 wherein said substrate is graphite and said layers are a metal selected from the group consisting of tungsten and tungsten-rhenium alloy.
6. An X-ray tube as set forth in claim 4 wherein said metallic coating is graphite.
7. An X-ray tube as set forth in claim 4 wherein said metallic coating is molybdenum.
8. An X-ray tube as set forth in claim 1 wherein the layer on the surface of the target facing the cathode is

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confined substantially to said selected portion thereof.

9. An X-ray tube as set forth in claim 1 wherein the layer on the surface of the target remote from the cathode varies in thickness in the radial direction.

10. An X-ray tube as set forth in claim 9 wherein the layer on the surface of the target remote from the cathode is substantially thicker in the area thereof opposite said selected portion of the target.

11. An X-ray tube as set forth in claim 1 wherein the layer more remote from the cathode is enclosed on both sides by material of the substrate.

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