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(54) **X-ray tube target**

(57) An X-ray tube anode target has a focal track coated with X-ray emissive material 44 (e.g. W-Realloy) and other surface portions coated with heat emissive material 48 comprising at least one of hafnium boride, hafnium oxide, hafnium nitride, hafnium silicide, and hafnium aluminide, on a substrate of Mo-W alloy for example. Alternatively the target is made of one of the X-ray emissive and heat emissive materials and is coated with the other material. The hafnium compounds are efficient heat radiators which allow the tube to run at a lower target temperature or with higher electron beam energy. Deposition by plasma spraying, sputtering, evaporation, vapour deposition, or spraying with a binder and sintering, are mentioned. Coating 48 may be 0.01 to 0.10 mms thick.

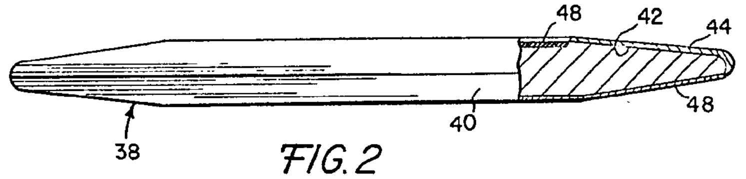

FIG. 2

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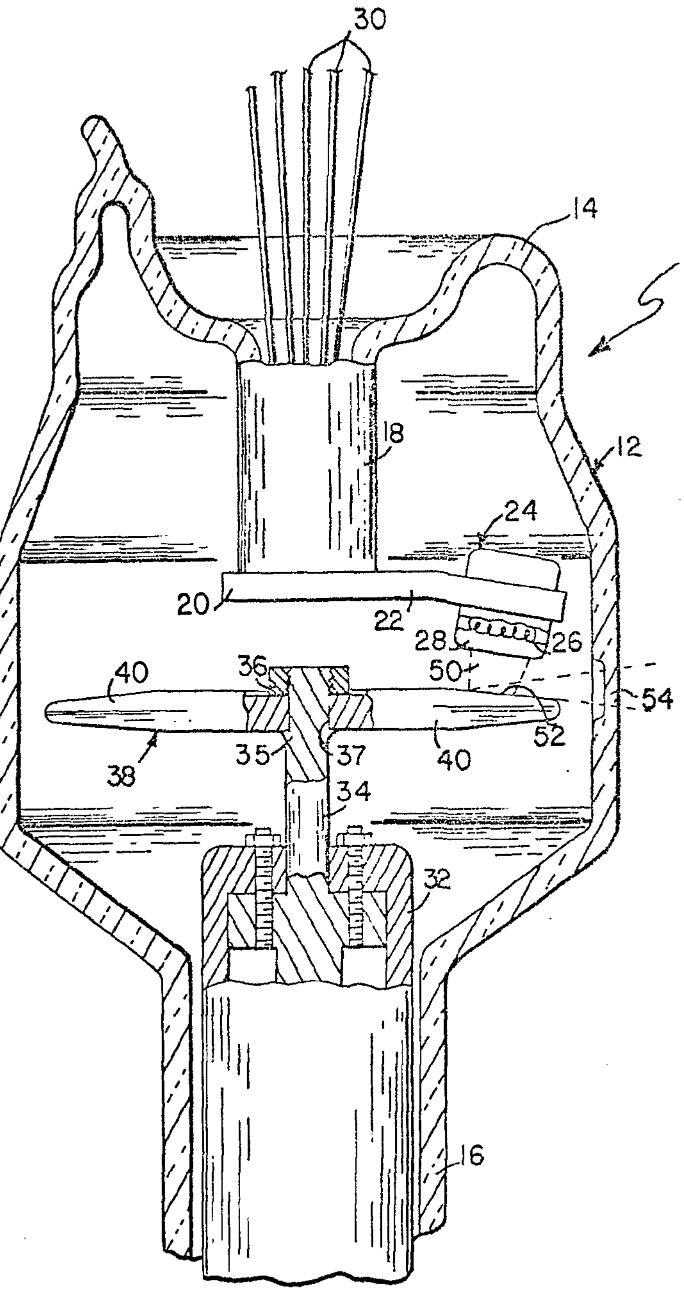

FIG. 1

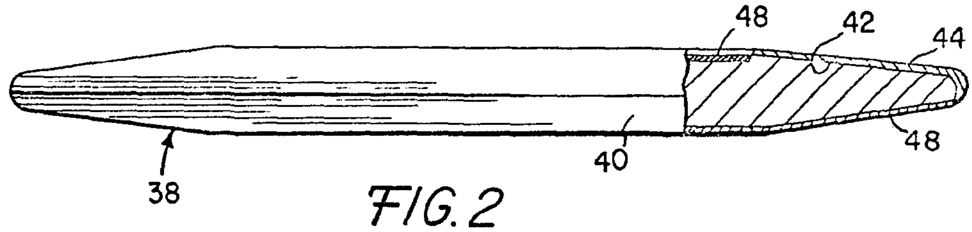

FIG. 2

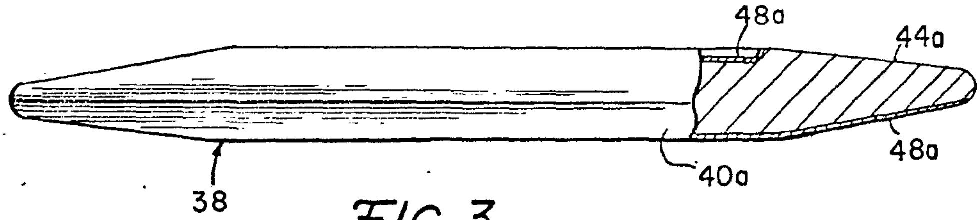

FIG. 3

SPECIFICATION

X-ray tube target

This invention relates generally to X-ray tubes and targets therefor, especially targets for rotating anode tubes.

Generally, an X-ray tube of the rotating anode type includes an evacuated envelope having therein an electron emitting cathode disposed to beam high energy electrons on to a focal spot area of an anode target. The target may comprise a rotatable disc having adjacent its outer periphery an annular focal track made of X-ray emissive material, such as a tungsten-rhenium alloy, for example. Thus, electrons beamed from the cathode may be focused on to a focal spot surface area of the focal track to penetrate onto the underlying material and generate X-rays which radiate therefrom and out of the tube.

Most of the electron energy incident on the focal spot area of the focal track is converted to heat energy which could become excessive and damage the surface of the focal track. Consequently, the target disc usually is mounted for rotation by having a central portion thereof attached to a stem end portion of a magnetic induction rotor which is supported by bearings in the envelope. Thus, an external stator encircling the rotor may be energized for rotating the rotor and attached disc to move successive radial segments of the focal track at a desired speed through the focal spot area aligned with the electron beam. As a result, localized overheating is avoided but the heat energy is accumulated in the body of the target and must be dissipated before the temperatures become excessive enough to cause warping or cracking of the disc.

However, the stem end portion of the rotor is generally provided with a reduced cross-sectional configuration for restricting the flow of heat from the attached disc to the rotor in order to prevent damage to the support bearings thereof. Therefore, the heat energy accumulated in the target disc cannot be dissipated efficiently by conduction through adjacent structure, and cannot be dissipated by convection since the tube envelope is evacuated. Consequently, the accumulated heat energy in the target disc is dissipated predominately by radiation to the tube envelope, which may be cooled by an insulting fluid, such as an X-ray transparent oil, for example.

Thus, it is advantageous and desireable to provide an X-ray tube with a target having an improved heat emissive surface for dissipating heat from the target.

According to the present invention, there is provided an X-ray target comprising a body having a first surface portion made of X-ray emissive material and a second surface portion made of a heat emissive material comprising at least one of hafnium boride, hafnium oxide, hafnium nitride, hafnium silicide, and hafnium aluminide.

The target body may be made of a first material having one surface portion coated with X-ray emissive material and another surface portion coated with the heat emissive material. As a first alternative, the target body may be made of X-ray emissive material and have a surface portion outside of the focal spot area coated with the heat emissive material. As a second alternative, the target body may be made of the heat emissive material and have a focal spot surface portion thereof with X-ray emissive material.

A preferred embodiment comprises an X-ray tube including a tubular envelope having rotatably mounted therein an anode target disc made of suitable lightweight material, such as a molybdenum-tungsten alloy, for example. Disposed on the disc and adjacent the outer periphery thereof is an annular focal track layer of efficient X-ray emissive material, such as a tungsten-rhenium alloy. The X-ray emissive material of the focal track layer is bonded to the material of the substrate disc, e.g. by chemical vapour deposition. Disposed on portions of the disc outside the focal track is a heat emissive coating of hafnium oxide material, which preferably has a thickness in the range of 0.01 to 0.10 mm. The hafnium oxide material is bonded to the material of the substrate disc, e.g. by plasma spraying, sputtering, evaporation, or chemical vapour deposition.

The invention will be described in more detail, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a fragmentary axial view, partly in section, of an X-ray tube embodying the invention;

Figure 2 is an enlarged elevational view, partly in section, of one embodiment of the X-ray target of this invention; and

Figure 3 is an enlarged elevational view, partly in section, of an alternative embodiment of the X-ray target of this invention.

In Fig. 1 an X-ray tube 10 of the rotating anode type has a tubular envelope 12 made of insulating material, e.g. glass. The envelope 12 is provided with a reentrant end portion 14 and an opposing neck portion 16. The reentrant end portion of envelope 12 is peripherally sealed to one end of a cathode support sleeve 18 made of rigid material, e.g. Kovar (Trade Mark). The cathode sleeve 18 extends axially within the envelope 12 and has an inner end sealed to a cap 20 which supports a radially extending, hollow arm 22.

The arm 22 is inclined with respect to a radius from the axis of cathode sleeve 18 and supports on a distal end portion thereof a conventional cathode head 24. The cathode head 24 includes an electron emitting filament 26 which is longitudinally disposed within a grid-type focusing cup 28. Electrical conductors 30 extend hermetically through the envelope and through the hollow arm 22 for connection to the filament 26 and the focusing cup 28 in a well-known manner.

Sealed within the next portion 16 of envelope 12 is a bearing mounted rotor 32 of a magnetic-type induction motor (the external stator of which is not shown). The rotor 32 extends axially within the envelope 12 and has attached to its inner end an axially extending stem 34. The stem 34 has an annular shoulder 35 supporting a transversely disposed anode target 38 having a central aperture 37 through which a threaded end portion of the stem 34 protrudes. The target 38 is fixed to the stem 34 by a nut 36 engaging the threaded end portion of stem 34, and is rotated by the rotor 32 in a well-known manner.

As shown in Fig. 2, the anode target 38 may comprise a substrate disc 40 made of lightweight material, e.g. a molybdenum-tungsten alloy. The disc 40 has a surface facing the cathode 24 and provided with a beveled annular marginal portion 42. Bonded on to the beveled surface portion 42 of disc 40 is an annular focal track 44 comprising a layer of efficient X-ray emissive material, e.g. a tungsten-rhenium alloy, applied by chemical vapour deposition.

Surface portions of disc 40 outside the focal track 44 are provided with a heat emissive coating 48 made of hafnium boride, hafnium oxide, hafnium nitride, hafnium silicide, hafnium aluminide or a mixture thereof. Thus, outside of the focal track 44, the anode target 38 is provided with surface portions made of material having greater emissivity than the sintered tungsten material which has been used for heat emissive coatings on known X-ray targets. The specified hafnium compounds also have melting points greater than 2000°C and vapour pressures less than one millionth of a Torr (1.33×10^{-4}Pa) at 1800°C. Furthermore, the specified hafnium compounds do not react with other materials used in the fabrication of conventional X-ray tubes and thereof do not degrade tube stability.

Accordingly, the emissive coating may be made of hafnium oxide, for example, which has excellent adhesion to the molybdenum material of the substrate disc 40. The material of heat emissive coating 48 is mechanically bonded and thermally coupled to the material of the disc 40 and may be deposited by plasma spraying, sputtering, evaporation, chemical vapour deposition, or spraying with a binder followed by high temperature sintering, for examples. Subsequently, loose particles may be removed from the heat emissive coating 48 by subjecting the coating to a process such as polishing or grid blasting, for examples. Preferably, the heat emissive coating 48 has a thickness between 0.01 mm and 0.10 mm.

In operation, electrical energy supplied through the conductors 30 heats the filament 26 of the cathode 24 to an electron emitting temperature, and maintains the focusing cup 28 at a suitable electrical potential for directing the emitted electrons into a beam 50 which impinges on an aligned focal spot area 52 of the focal track 44. The focal spot area 52 may be of conventional size, such as 1 mm wide by 5 mm extended radially along the slopė of the focal track. Also, the anode target 38 is maintained at a sufficiently high electrical potential, such as 80kV, with respect to the cathode filament 26 to accelerate electrons in the beam 50 to high kinetic energy levels. As a result, the electrons impinging on the focal spot surface area 48 of focal track layer 44 penetrate into the underlying X-ray emissive material to generate X-rays. Thus, X-rays radiating from the focal spot area 52 pass in a beam though a radially aligned, X-ray transparent window 54 in the envelope 12.

However, most of the electron energy incident on the focal spot area 52 is converted into heat within the underlying material of the focal track 44. Consequently, the target disc 40 is rotated at an appropriately high angular velocity, such as 10,000 rpm, to move successive segments of the annular focal track 44 rapidly through the focal spot 48. The heat developed in respective segments of focal track 44, while in the focal spot area 48, is conducted to relatively cooler portions of the target disc 40 outside the focal track. In this manner, the segments of focal track 44, when rotated out of the focal spot area 52, can have their temperature reduced to relatively safe values for re-entering the focal spot area.

Thus heat is accumulated in the body of the target disc 40 for dissipation through the surrounding tube structure before becoming so excessive as to cause damage, such as warping or cracking of the target disc. However, the envelope 12 is evacuated and the stem 32 has a minimum cross-sectional area to restrict the flow of heat to the rotor 32 in order to avoid damaging the support bearings thereof. Accordingly, the heat accumulated in the body of the target disc 40 is dissipated predominantly by radiation to the envelope 12 which may be cooled by immersion in an insulating fluid such as an X-ray transparent oil. As a result, the emissivity capability of the target disc 40 is a limiting factor in determining the maximum amount of electron energy that can be incident on the focal spot area 52 and, consequently, the maximum X-ray intensity that can be obtained from the tube.

Therefore, surface portions of the target disc 40 outside the focal track 44 are mechanically bonded and thermally coupled to the hafnium oxide material of the heat emissive coating 48. Hafnium oxide, which has an emissivity of about six-tenths, is approximately 35% more effective in dissipating heat than the conventional sintered tungsten material, which has an emissivity of about three-tenths. In comparison tests between a first group of X-ray tubes having target discs provided with heat emissive coatings of hafnium oxide and a second group of X-ray tubes having target discs provided with heat emissive coatings of sintered tungsten material, the target discs of the first group had focal tracks which operated about 90° to 100°C cooler than target disc focal tracks of the second group. Also, in order to bring target disc focal tracks of the first group up to the operating temperatures of the target disc focal tracks of the second group, the input power to the tubes of the first group required about a 20% increase. Thus, the X-ray tubes having target discs provided with heat emissive coating of hafnium oxide can be operated at lower focal track temperatures or a higherr input power levels, as compared to the X-ray tubes having target discs provided with heat emissive coatings of conventional sintered tungsten material.

As shown in Fig. 3, the X-ray target 38 alternatively may comprise an axially rotatable disc 40a made of efficient X-ray emissive material, such as tungsten-rhemium alloy, for example. The disc 40a may have adjacent its outer periphery an annular focal track 44a comprising an uncoated disc portion which is sloped radially toward the outer periphery of the disc and disposed in spaced opposing relationship with the cathode 24. The surface portions of disc 40a outside the focal track 44a are provided with a heat emissive coating 48a of hafnium oxide material, which is mechanically bonded and thermally coupled to the material of the disc 40a.

As another alternative, the X-ray target 38 may include an axially rotatable disc made of heat emissive material comprising at least one of the specified hafnium compounds and have adjacent its outer periphery an annular focal track layer maxe of X-ray emissive material, as is shown in fig. 2 for example. Also, although the X-ray target 38 has been shown herein as a generally flat disc, it may equally well have other configurations, such as cup-shaped, for example. Furthermore, although the emissive coating is shown on both major surfaces of the target disc; it may be provided on only one surface portion of the substrate disc.

CLAIMS

1. An X-ray target comprising a body having a first surface portion made of X-ray emissive material and a second surface portion made of a heat emissive material comprising at least one of hafnium boride, hafnium oxide, hafnium nitride, hafnium silicide, and hafnium aluminide.

2. An X-ray target according to claim 1, wherein the body is a rotatable disc.

3. An X-ray target according to claim 2, wherein the first surface portion is annular and disposed adjacent the outer periphery of the disc.

4. An X-ray target according to claim 1, 2 or 3, wherein the body is made of a first material and the first and second portions are coated with the X-ray emissive and heat emissive materials respectively.

5. An X-ray target according to claim 1, 2 or 3, wherein the body is made of the X-ray emissive material and the second surface portion is coated with the heat emissive material.

6. An X-ray target according to claim 1, 2 or 3, wherein the body is made of the heat emissive material and the first surface portion is coated with the X-ray emissive material.

7. An X-ray tube including an evacuated envelope, and a cathode and an X-ray target according to any of claims 1 to 6 mounted in the envelope.

8. An X-ray tube according to claim 7, wherein the target is a rotating anode target.

9. An X-ray tube substantially as hereinbefore described with reference to and as illustrated in Figs. 1 and 2 or Figs. 1 and 3 of the accompanying drawings.

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