July 22, 1941. Z. J. ATLEE 2,250,322

ANODE AND ALLOY FOR MAKING SAME

Filed March 6, 1939

FIG. 1.

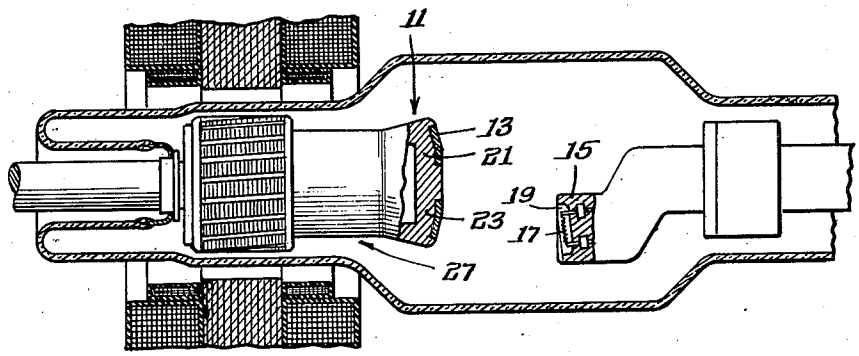


FIG. 2.

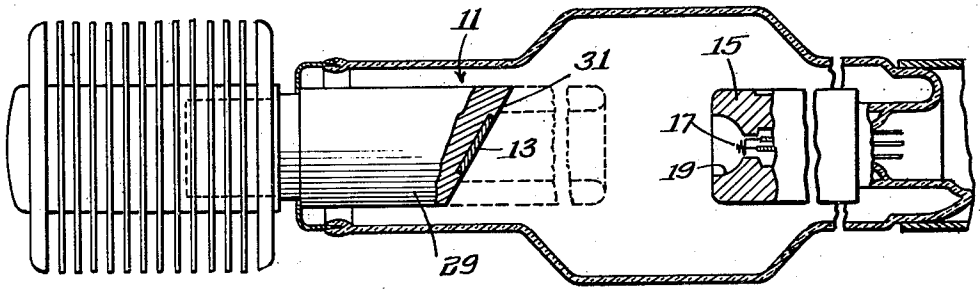


FIG. 3.

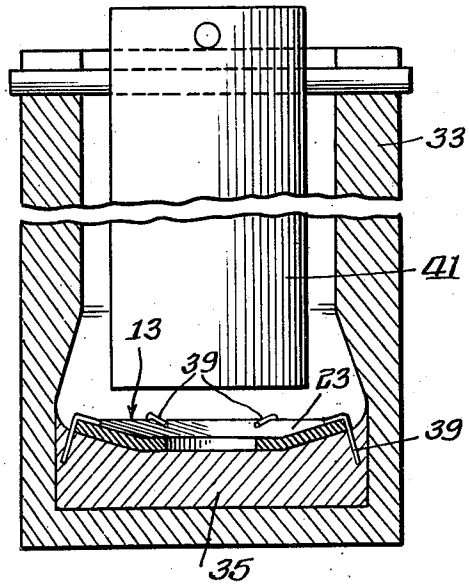
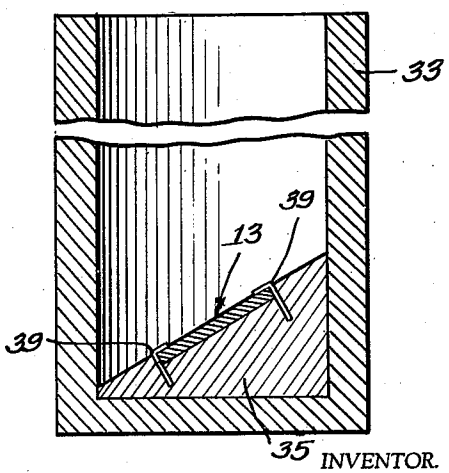


FIG. 4.



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ANODE AND ALLOY FOR MAKING SAME

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39 Claims. (Cl. 250—149)

This invention relates in general to the production of X-rays, and has more particular reference to anodes and anode material for use in X-ray generators and like equipment.

An important object of the invention is to provide an improved anode characterized by the ability to stand up under the relatively high temperatures to which the same is exposed in service during the operation of the X-ray generator, without failure due to cracking.

Another important object is to provide an improved alloy material particularly well adapted for use in the formation of anodes, having high heat conductivity and relatively small grain, and consequently highly resistant to the development of cracks when heated.

Another important object resides in providing an improved method of treating a copper alloy, whereby to precipitate a medium between the grain boundaries of the alloy whereby to increase the hardness and tensile strength, the method serving also to inhibit grain growth upon heating of the alloy, whereby to provide a preferably copper alloy particularly well adapted for high temperature service and in which there is little, if any, tendency toward cracking of the material due to grain growth when heated excessively.

These and other objects of the invention will become apparent from the following description, which, taken in connection with the accompanying drawing, discloses preferred embodiments of the invention and the manner of practicing the same.

Referring to the drawing,

Figure 1 is a view of a rotating anode embodying my present invention, and its cooperating cathode as applied in an X-ray generator;

Figure 2 is a sectional view taken through an anode of the stationary type; and

Figures 3 and 4 are sectional views through molds in which the anodes shown in Figures 1 and 2 may be fabricated as castings.

To illustrate my invention, I have shown in the drawing anode means 11 comprising a copper alloy body, the material of which embodies certain desirable characteristics hereinafter more fully described, said body carrying target means 13 imbedded therein. The anode means and its target are adapted to be enclosed in an evacuated, usually glass, envelope, together with cathode means 15, so that by electrically energizing the anode and cathode, X-rays may be generated in accordance with known principles.

As shown in Figure 1, the cathode 15 may comprise a filament 17 suitably mounted in a focusing cup 19 disposed in position to direct a stream of electrons upon the target 13. The anode means 11, as shown in Figure 1, may comprise a disk 21 carrying the target 13 in the form of an annular band 23 imbedded in the peripheral portions of the disk 21, said disk 21 being mounted for rotation on a suitable shaft or stem 25 by the fastening means 27.

My invention, however, is not necessarily restricted to an anode of the rotating type shown in Figure 1, and may simply comprise a preferably cylindrical body 29 comprising a copper alloy having the desired characteristics hereinafter described more fully, the body 29 having an inclined face 31 in which the target means 13 is imbedded.

It should be understood that the impingement of electrons, emitted by the cathode 15, upon the target 13 for the production of X-rays, causes the generation of substantial amounts of heat in the anode. I have observed that ordinary copper, which has an annealing or recrystallization temperature of 165° C., when utilized as a material for the formation of the body of the anode, does not resist in satisfactory manner the temperatures to which the anode is thus subjected in service. Ordinary copper and other anode materials have a tendency toward the development of cracks in the body of the anode due, in part, to grain growth and uneven heating and cooling. The cracks usually initially occur adjacent the target 13, in the vicinity of which the body is at maximum temperature, the cracks spreading thence throughout the body of the anode. Such cracks insulate the body against the free passage of heat therethrough and prevent the heat generated at the target from dissipating by conduction through the anode body to such an extent that the target becomes burned and useless.

The development of cracks is particularly noticeable in rotating anodes in which the size and mass of the anode body, and consequently its heat dissipating ability, is made as small as possible, due to the rotating character of the anode and the necessity of maintaining the rotating mass as small as possible. In stationary anodes of the type illustrated in Figure 2, the problem of anode cracking is also present, although to a lesser degree than in rotating anodes, since a stationary anode may be designed with more nearly adequate heat conducting sectional areas than is the case in rotating anodes.

The development of grain growth in copper alloy anodes under the action of heat in service

results in the cracking of the anode base. The development of such cracks provides heat insulation, thus preventing the anode from transmitting and dissipating the heat generated at the target as rapidly as it should. Under such circumstances, the target may become overheated, with resulting pitting and cracking, thereby rendering the same useless.

Anode cracks may develop in position extending longitudinally through the body of the anode, thus providing gas leak paths through the cracked anode communicating the interior of the lamp envelope with its exterior in structures where the anode is sealed in the envelope by a glass-to-metal seal, thus also rendering the entire device inoperative due to gas leakage therein through such cracks.

An anode for an X-ray generator, whether of the stationary or rotating type, may be fabricated by casting the anode material in a suitable mold in which has been anchored the target means **13**. In Figure 3 of the drawing, I have shown a mold for casting an anode of the stationary type, said mold comprising suitable walls **33** and an inclined bottom **35** formed with a socket **37** for receiving the target means **13**. The target means **13** may comprise any suitable material, preferably tungsten, although platinum, rhenium, uranium, and other metals, may be employed.

The target means preferably comprises a material having a high melting point and may comprise any of the metals having an atomic number falling between 72 and 92, and rhenium and tungsten for practical reasons are preferred. The principal advantage of rhenium over tungsten is than rhenium is ductile and therefore has less tendency to develop cracks when subjected to excessive high temperatures as at the focal spot in the target of an X-ray generator, and a rhenium target will successfully resist temperatures substantially in excess of the temperatures at which targets comprising tungsten fail. Tungsten is a non-elastic substance, so that when the focal spot becomes overheated, as by the development of cracks in the base and consequent failure of heat dissipation, the target itself tends to crack at the marginal edge of the focal spot.

For an anode of the stationary type, the target means may be formed as a disk-like button, the anode means **13** for a rotating anode comprising an annular band, as clearly shown in Figure 1. It is ordinarily necessary, in casting the anode material upon the target means, to anchor the latter upon the bottom of the mold in which the anode is cast, in order to prevent the displacement of the target means in the mold, and to this end I have shown, in Figure 3, the target means **13** anchored in place by means of holding wires **39** applied through suitable perforations in the casting mold and having ends bent over upon the target means in the mold, the remote ends of the wires extending outwardly through the openings in the mold and being bent outwardly thereof to retain the same, and the target means, in place. After the anode body has been formed as a casting in the mold, the formed anode may be removed, and the outer portions of the holding wires **39** may be snipped off.

The present invention contemplates the fabrication of the body **11** of the anode of a heat treatable copper alloy having high conductivity and hardness, and a relatively high annealing or recrystallization temperature; and I have developed a predominantly copper alloy, having chromium as an alloy constituent, that affords a satisfactory crack-resisting anode material having the foregoing desired characteristics.

The chromium constituent preferably comprises a quantity of chromium of the order of 0.5 per cent. This crack-resisting alloy may be fabricated to form an anode by casting the same, in molten state, upon the target means **13** which preferably comprises a preformed piece of tungsten, rhenium or other suitable target material. I have encountered difficulty in causing the copper-chromium alloy to "weld" to the target material because the alloy does not readily "wet" the target material, especially if the same comprises tungsten. In order to enable the alloy to "wet" the target material, I may add, as an alloy ingredient, a suitable deoxidizing agent, such as beryllium, lithium, boron or calcium, and for this purpose beryllium particularly, and lithium, are especially well adapted. The deoxidizing medium may and preferably does comprise approximately 1 per cent of the total alloy constituents. A satisfactory formula is:

	Per cent by weight
Copper	98.5
Beryllium	1.0
Chromium	0.5

The heat treating schedule to which I preferably subject the alloy, in order to produce the desired hardness, conductivity and non-cracking characteristics, contemplates the heating of the material to at least 900° C., which, of course, may be accomplished as a step in the initial formation of the alloy, if desired, or in melting the alloy for casting the same in a mold or die. The alloy should then be cooled rapidly, and the cooling operation should be sufficiently rapid to preserve the chromium constituent for precipitation between the grain boundaries in the casting during the subsequent hardening operation. Unless the casting is cooled rapidly, the chromium constituent tends to escape from the casting, partly by evaporation, but mostly by migration to the surface of the casting where the chromium constituent becomes oxidized. After being rapidly cooled, as aforesaid, the alloy may then be hardened by heating at 500° C. for from two to four hours, depending upon the size of the piece.

Under ordinary circumstances, cooling by quenching in water would be satisfactory from the standpoint of rapidity of cooling, but quenching in water tends to damage the target means **13** if the same comprises tungsten.

In accordance with my present invention, the alloy is cast into the mold and around the target means **13** in a vacuum casting furnace of standard construction, and is therefore cooled under vacuum at a rate sufficiently rapid to preserve the chromium constituent as aforesaid.

After the casting has thus been cooled in the casting furnace, it may be and preferably is immediately assembled, without further treatment, in the envelope of an X-ray tube and is there subjected for several hours to a bakeout process at approximately 500° C., while the tube envelope is connected with an exhaust pump. During the bakeout process, the anode may be subjected to electrical bombardment, and this bombardment, together with the bakeout process, provides sufficient heat treatment at 500° C. to actually increase the hardness of the anode by causing the precipitation of chromium between the grain boundaries in the casting.

Precipitation of chromium in this fashion, by heat treatment at 500° C., not only increases the hardness of the alloy but also increases its tensile strength. After heat treatment, the allow has an annealing temperature of the order of 500° C., that is to say, no grain growth or decrease in hardness will occur so long as the temperature of the anode is not allowed to exceed 500° C.

Embodied in an X-ray generator, the anode may safely develop operating temperatures of the order of 400° C. and up to a maximum of 500° C., without danger of failure due to cracking; and the alloy has heat conducting ability equal to 75 per cent that of copper at room temperature, and 90 per cent that of copper at 400° C., being thus substantially ideal for the purpose herein described. While hardness is a desirable characteristic, high heat conductivity is essential in order to permit rapid dissipation of heat from the point of generation thereof at the target, thus ruling out other alloys of copper that are of superior hardness and having higher annealing temperatures. It is essential not only to utilize a material having a relatively high annealing temperature to inhibit grain growth at the operating temperatures to which the anode is subjected in service, but also to provide a material having high heat conductivity.

It is thought that the invention and numerous of its attendant advantages will be understood from the foregoing description, and it is obvious that numerous changes may be made in the form, construction and arrangement of the several parts without departing from the spirit or scope of the invention, or sacrificing any of its attendant advantages, the form herein described being a preferred embodiment for the purpose of illustrating the invention.

The invention is hereby claimed as follows:

1. An anode comprising a stem of predominantly copper allow containing a hardening material as an alloy constituent in quantities of the order of 0.5 per cent, said alloy having a recrystallization temperature in excess of 400° C. and having heat conducting ability in excess of 50 per cent of that of pure copper at room temperature, and having hardness in excess of 50 Rockwell E scale.

2. An anode comprising a stem of copper alloy including a hardening material of the class including chromium and cobalt in quantities of the order of 0.5 per cent as an alloy constituent and adapted for heat treatment to harden the same by precipitation of the hardening constituent between grain boundaries in the material.

3. An anode comprising a stem of copper alloy including chromium in quantities of the order of 0.5 per cent as an alloy constituent and adapted for heat treatment to harden the same by precipitation of the chromium between grain boundaries in the material.

4. An anode comprising a stem of copper alloy including cobalt in quantities of the order of 0.5 per cent as an alloy constituent and adapted for heat treatment to harden the same by precipitation of the cobalt between grain boundaries in the material.

5. An anode comprising a stem of predominantly copper alloy comprising chromium as an alloy constituent in quantities of the order of 0.5 per cent.

6. An anode comprising a stem of predominantly copper alloy comprising cobalt as an alloy constituent in quantities of the order of 0.5 per cent.

7. An anode comprising a stem of predominantly copper alloy containing, as alloy constituents, a hardening material in quantities of the order of 0.5 per cent and a deoxidizing agent in quantities of the order of 1 per cent, said alloy having a recrystallization temperature in excess of 400° C. and having heat conducting ability in excess of 50 per cent of that of pure copper at room temperature and having hardness in excess of 50 Rockwell E scale.

8. An anode comprising a stem of predominantly copper alloy including a hardening agent of the class including chromium and cobalt in quantities of the order of 0.5 per cent, together with a deoxidizing agent of the class including beryllium, lithium, calcium and boron in quantities of the order of 1 per cent, whereby to improve the wetting characteristics of the alloy.

9. An anode comprising a stem of predominantly copper alloy comprising chromium as an alloy constituent in quantities of the order of 0.5 per cent, together with beryllium as a wetting agent in quantities of the order of 1 per cent.

10. An anode comprising a stem of predominantly copper alloy comprising chromium as an alloy constituent in quantities of the order of 0.5 per cent, together with lithium as a wetting agent in quantities of the order of 1 per cent.

11. An anode comprising a stem of predominantly copper alloy comprising chromium as an alloy constituent in quantities of the order of 0.5 per cent, together with calcium as a wetting agent in quantities of the order of 1 per cent.

12. An anode comprising a stem of predominantly copper alloy comprising chromium as an alloy constituent in quantities of the order of 0.5 per cent, together with boron as a wetting agent in quantities of the order of 1 per cent.

13. An anode comprising a stem of predominantly copper alloy comprising cobalt as an alloy constituent in quantities of the order of 0.5 per cent, together with beryllium as a wetting agent in quantities of the order of 1 per cent.

14. An anode comprising a stem of predominantly copper alloy comprising cobalt as an alloy constituent in quantities of the order of 0.5 per cent, together with lithium as a wetting agent in quantities of the order of 1 per cent.

15. An anode comprising a stem of predominantly copper alloy comprising cobalt as an alloy constituent in quantities of the order of 0.5 per cent, together with calcium as a wetting agent in quantities of the order of 1 per cent.

16. An anode comprising a stem of predominantly copper alloy comprising cobalt as an alloy constituent in quantities of the order of 0.5 per cent, together with boron as a wetting agent in quantities of the order of 1 per cent.

17. An anode comprising a stem of predominantly copper alloy containing a hardening material as an alloy constituent in quantities of the order of 0.5 per cent, said alloy having a recrystallization temperature in excess of 400° C. and having heat conducting ability in excess of 50 per cent of that of pure copper at room temperature and having hardness in excess of 50 Rockwell E scale, and a target integrated in the said stem and comprising a metal of the class having an atomic number within the range 72–92 and including tungsten, platinum, rhenium and uranium.

18. An anode comprising a stem of predominantly copper alloy including a hardening agent of the class including chromium and cobalt in quantities of the order of 0.5 per cent as an alloy constituent, together with a deoxidizing agent of

the class including beryllium, lithium, calcium and boron to improve the wetting characteristics of the alloy, and a target integrated with said stem and comprising a metal of the class having an atomic number within the range 72–92 and including tungsten, platinum, rhenium and uranium.

19. An anode comprising a stem of predominantly copper alloy comprising chromium as an alloy constituent in quantities of the order of 0.5 per cent, together with beryllium as a wetting agent in quantities of the order of 1 per cent, and a target comprising a metal of the class having an atomic number within the range 72–92 and including tungsten, platinum, rhenium and uranium integrated on the stem in intimate heat transferring relationship therewith, said stem being configurated to rapidly dissipate heat generated at said target.

20. An anode comprising a stem of predominantly copper alloy comprising chromium as an alloy constituent in quantities of the order of 0.5 per cent, together with lithium as a wetting agent in quantities of the order of 1 per cent, and a target comprising a metal of the class having an atomic number within the range 72–92 and including tungsten, platinum, rhenium and uranium integrated on the stem in intimate heat transferring relationship therewith, said stem being configurated to rapidly dissipate heat generated at said target.

21. An anode comprising a stem of predominantly copper alloy comprising chromium as an alloy constituent in quantities of the order of 0.5 per cent, together with calcium as a wetting agent in quantities of the order of 1 per cent, and a target comprising a metal of the class having an atomic number within the range 72–92 and including tungsten, platinum, rhenium and uranium integrated on the stem in intimate heat transferring relationship therewith, said stem being configurated to rapidly dissipate heat generated at said target.

22. An anode comprising a stem of predominantly copper alloy comprising chromium as an alloy constituent in quantities of the order of 0.5 per cent, together with boron as a wetting agent in quantities of the order of 1 per cent, and a target comprising a metal of the class having an atomic number within the range 72–92 and including tungsten, platinum, rhenium and uranium integrated on the stem in intimate heat transferring relationship therewith, said stem being configurated to rapidly dissipate heat generated at said target.

23. An anode comprising a stem of predominantly copper alloy comprising cobalt as an alloy constituent in quantities of the order of 0.5 per cent, together with beryllium as a wetting agent in quantities of the order of 1 per cent, and a target comprising a metal of the class having an atomic number within the range 72–92 and including tungsten, platinum, rhenium and uranium integrated on the stem in intimate heat transferring relationship therewith, said stem being configurated to rapidly dissipate heat generated at said target.

24. An anode comprising a stem of predominantly copper alloy comprising cobalt as an alloy constituent in quantities of the order of 0.5 per cent, together with lithium as a wetting agent in quantities of the order of 1 per cent, and a target comprising a metal of the class having an atomic number within the range 72–92 and including tungsten, platinum, rhenium and uranium integrated on the stem in intimate heat transferring relationship therewith, said stem being configurated to rapidly dissipate heat generated at said target.

25. An anode comprising a stem of predominantly copper alloy comprising cobalt as an alloy constituent in quantities of the order of 0.5 per cent, together with calcium as a wetting agent in quantities of the order of 1 per cent, and a target comprising a metal of the class having an atomic number within the range 72–92 and including tungsten, platinum, rhenium and uranium integrated on the stem in intimate heat transferring relationship therewith, said stem being configurated to rapidly dissipate heat generated at said target.

26. An anode comprising a stem of predominantly copper alloy comprising cobalt as an alloy constituent in quantities of the order of 0.5 per cent, together with boron as a wetting agent in quantities of the order of 1 per cent, and a target comprising a metal of the class having an atomic number within the range 72–92 and including tungsten, platinum, rhenium and uranium integrated on the stem in intimate heat transferring relationship therewith, said stem being configurated to rapidly dissipate heat generated at said target.

27. An anode comprising a stem of predominantly copper alloy containing a hardening material as an alloy constituent in quantities of the order of 0.5 per cent, said alloy having a recrystallization temperature in excess of 400° C. and having heat conducting ability in excess of 50 per cent of that of pure copper at room temperature and having hardness in excess of 50 Rockwell E scale, and a target integrated in the said stem and comprising rhenium.

28. An anode comprising a stem of predominantly copper alloy containing, as alloy constituents, a hardening material in quantities of the order of 0.5 per cent and a deoxidizing agent in quantities of the order of 1 per cent, said alloy having a recrystallization temperature in excess of 400° C. and having heat conducting ability in excess of 50 per cent of that of pure copper at room temperature and having hardness in excess of 50 Rockwell E scale, and a target integrated in the said stem and comprising rhenium.

29. An anode comprising a stem of copper alloy including a hardening material of the class including chromium and cobalt in quantities of the order of 0.5 per cent as an alloy constituent and adapted for heat treatment to harden the same by precipitation of the hardening constituent between grain boundaries in the material, and a target integrated in the said stem and comprising rhenium.

30. An anode comprising a stem of predominantly copper alloy including a hardening agent of the class including chromium and cobalt in quantities of the order of 0.5 per cent as an alloy constituent, together with a deoxidizing agent of the class including beryllium, lithium, calcium and boron to improve the wetting characteristics of the alloy, and a target integrated with said stem and comprising rhenium.

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