

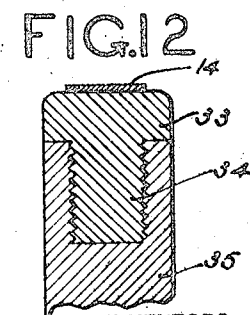
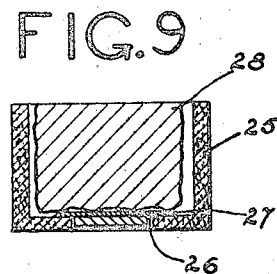
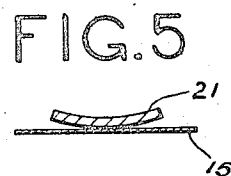
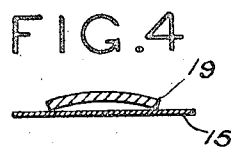
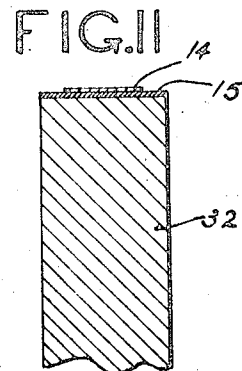
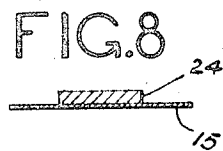
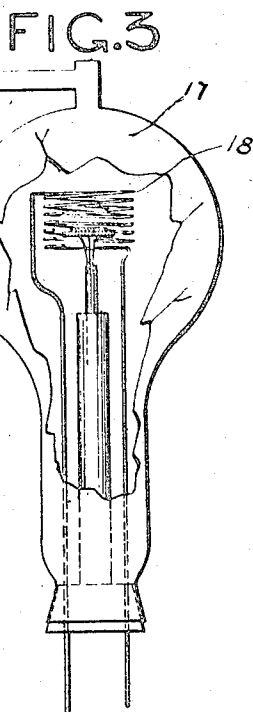
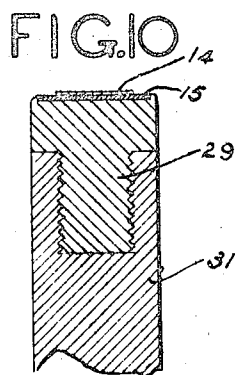
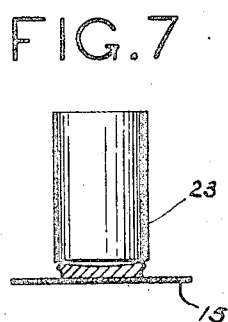
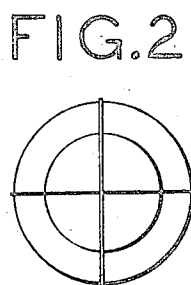
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J. W. MARDEN ET AL

1,733,744

COMPOSITE X-RAY TARGET

Filed Jan. 16, 1926



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## UNITED STATES PATENT OFFICE

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## COMPOSITE X-RAY TARGET

Application filed January 16, 1926. Serial No. 81,645.

This invention relates to X-ray targets and more particularly to a composite X-ray target composed at least partially of thorium or uranium, i. e., metals whose oxides are irreducible by hydrogen.

It has been customary in the manufacture of composite X-ray targets consisting of a body of copper and a tungsten insert or button to melt the copper around the tungsten insert. Considerable difficulty, however, is encountered in the manufacture of composite targets in which the insert is thorium or uranium for the reason, in the case of thorium, it alloys with the copper and forms an inter-metallic compound which has the formula  $\text{ThCu}_4$ . This compound is very hard and brittle and when the button is heated the thorium breaks loose from the copper. This alloy is a poor conductor of heat and prevents the proper heat conduction from the focal spot or button. In addition, owing to the difference in expansion of the two metals, the copper having a co-efficient of expansion which is about 30 per cent greater than that of thorium, there is danger of permanent separation of the metals when the target is heated beyond the temperature at which the copper will restore itself to its original shape.

Thorium and uranium are more suitable than tungsten or platinum for X-ray purposes since they possess superior ray-radiating properties since the atomic weights of thorium and uranium are greater. The melting points of thorium and uranium are however, less than that of tungsten.

Owing to the high heat-conductivity of such metals as copper, silver and gold, it is preferable to insert a thorium button directly into such metals, but owing to the alloying effect between thorium and these metals and the difference of co-efficient of expansion therebetween as mentioned above, it is difficult to form a composite target thereof.

This difficulty has been overcome, by the present invention, by the provision of an in-

termediate material between the thorium or uranium and copper which material will unite satisfactorily to the copper without the formation of an alloy and which will also wet the thorium or uranium so as to form a perfect bond therewith. The material which has been found to be most satisfactory for this intermediate bonding agent is tantalum, although molybdeum has also been found to be suitable for this purpose. The invention contemplates, however, the use of other bonding materials such as tungsten, or in fact any material which has a heat-conductivity as high or higher than thorium and with which both thorium and uranium and copper form an intimate contact.

Therefore, the main characteristics requisite for a composite target developed by the present invention are: (1) that the thorium or uranium intimately unites or is held to a backing of copper or other high heat-conductivity metal by means of an intermediate bonding material which is capable of surface-holding the other materials; (2) the use of an intermediate bonding material in which the co-efficient of expansion is not utilized in any way for holding the thorium or uranium button in place or for making intimate contact; (3) the utilization as the intermediate bonding material of a metal having approximately the same mass as the thorium or uranium button but having a smaller mass than the backing metal to which it is united and (4) the elimination of any welding compounds or brazing mixtures in producing the union between the metals forming the composite target.

It is an object of the present invention to provide a composite target having a thorium or uranium button united intimately with a backing material which will conduct the heat with sufficient rapidity to prevent the thorium or uranium from becoming over-heated or melting.

Another object of the invention is to pro-

vide a composite target consisting of a thorium or uranium button or disk intimately united to a backing material such as copper in such manner that the contact therebetween is maintained when the thorium or uranium is heated to near its melting point.

Another object of the invention is to provide a method of joining thorium or uranium to a body of good heat-conductivity to form a serviceable X-ray target or anode.

A further object of the invention is to provide a composite target having a thorium or uranium button or disk united to a body of large mass by means of an intermediate body having the same mass as the thorium or uranium button but which is capable of forming an intimate union with the backing material and the thorium or uranium.

A still further object of the invention is to provide a composite target for X-ray tubes and the like having a thorium or uranium button or disk joined to a material of good heat-conductivity by an intermediate body of metal having a co-efficient of expansion which is not a factor in maintaining the contact.

A more specific object of the invention is to provide a composite target for X-ray tubes and the like consisting of a thorium button or disk united to a copper backing by a metal such as tantalum or molybdenum.

A still more specific object of the invention is to provide a composite target for X-ray tubes and the like consisting of a thorium or uranium button which is relatively thin and which is united to a copper backing by means of a relatively thin disk of tantalum.

Other objects of invention will become apparent as the following description is read, taken in conjunction with accompanying drawings in which:

Fig. 1 is a crosssectional view of a button or disk of compressed thorium or uranium powder temporarily secured by means of wire to the intermediate bonding material such as tantalum, prior to being heat-treated.

Fig. 2 is a plan view of the material shown in Fig. 1.

Fig. 3 is an elevational view, partly broken away, of a high-vacuum high-frequency induction furnace showing a thorium or uranium button on a disk of tantalum in position to be heat-treated.

Fig. 4 is a crosssectional view of the disk of thorium as it appears after the preliminary heat-treatment.

Fig. 5 is a crosssectional view of a disk of thorium on the intermediate bonding material ready to receive a second heat-treatment.

Fig. 6 is a crosssectional view of a thorium or uranium button on a disk of tantalum, the former being fused thereto, said view showing these metals after they have received the second heat-treatment.

Fig. 7 is an elevational view, partly in cross-section, showing the method pursued in com-

pacting the thorium or uranium after having received the second heat-treatment.

Fig. 8 is a crosssectional view showing the thorium or uranium united to the intermediate bonding material and after the same has been compacted and trimmed to shape.

Fig. 9 is a view of a graphite crucible in which the partially finished target shown in Fig. 8 is inserted and in which the copper is placed for the purpose of melting the same around and to the intermediate bonding material.

Fig. 10 is a crosssectional view of a composite X-ray target embodying the present invention and in which the thorium or uranium button has been reduced in thickness.

Fig. 11 is a view similar to Fig. 10 but in which the shank of the target is composed of one piece of copper or a similar good heat-conducting metal, and

Fig. 12 is a crosssectional view of a composite target in which the thorium or uranium button is shown directly united to a massive body of tantalum or the like.

A composite target manufactured in accordance with present invention may be produced by forming a button 14 from a good grade of thorium or uranium powder. This button is formed by pressing the same into a disk of the desired diameter and of relatively small mass. After being formed, the pressed button is placed upon a disk of tantalum or similar material of relatively small mass to serve as a bonding agent. These two bodies are then secured together by tying with tungsten or molybdenum wire 16 of small diameter.

The next step in the process is to heat-treat the thorium so as to sinter the same. This is accomplished by inserting the tantalum disk with the thorium or uranium button 14 thereon in a high-vacuum furnace 17 containing a high frequency induction coil 18 said furnace being more fully described and illustrated in Patent 1,480,301. After the furnace has been evacuated to a high degree, the tantalum disk and thorium or uranium button are heated slowly until the adsorbed and absorbed gases are driven off from the thorium or uranium, the vacuum pump connected to the furnace being kept in operation throughout the heating of the material. After the gases have been pumped away and the thorium thoroughly degasified, the temperature is raised to just below the melting point of thorium or uranium by circulating eddy currents in the materials by high-frequency induction. It will be found that during the heat-treatment operation just mentioned, the thorium or uranium becomes distorted and assumes a concavo-convex form 19, being in contact with the tantalum around its marginal edges, this being due probably to the shrinkage of the thorium or uranium on the tantalum disk. The appearance of the materials at this time is illustrated in Fig. 4.

After, the furnace has been allowed to cool, the button of thorium or uranium and disk of tantalum are removed and the button 21 of thorium or uranium inverted in a manner similar to that shown in Fig. 5; thereafter the two disks are replaced in the furnace and, after evacuation, the heating is continued until the thorium or uranium begins to melt and until the tantalum disk and the thorium or uranium button have the appearance 22 in the furnace as illustrated in Fig. 6. It appears that the thorium or uranium during this second heat-treatment melts at the center first and the liquid thorium or uranium welds the major portion of the button on to the tantalum disk into a uniform solid mass.

After cooling, the thorium or uranium and tantalum, which are now welded or fused together, are removed from the furnace and this composite body subjected to pressure by means of a hardened steel plunger 23 which is forced against the button. This produces an effect corresponding to that obtained by mechanical working so that the thorium or uranium is in a very compact state.

After the compression step, the composite body of thorium or uranium and tantalum is placed in a lathe and turned down to the shape 24 illustrated in Fig. 8. This composite body is then inserted into a graphite container 25 (Fig. 9) having an opening 26 in the bottom thereof of a size equal to that of the button with the edges 27 of the tantalum disk resting upon the marginal edges of the opening. In order to provide a tight joint between the tantalum disk and the bottom of the crucible, it is customary to place a little flake of graphite or aquadag in the joint. Previously vacuum-fused copper 28 is placed on top of the tantalum disk 27 so as to very nearly fill the crucible 25. This crucible with its contents is then placed in the vacuum furnace, illustrated in Fig. 3, and after a good vacuum has been obtained, high frequency currents are again circulated through the primary coil of the furnace which results in the copper being melted. The copper is maintained in the molten condition for a period of two minutes or longer in order to afford an opportunity for any gas bubbles to escape therefrom. After cooling, the crucible with its contents is removed from the furnace. The copper backing and the tantalum with the thorium and uranium adhering thereto is removed from the crucible and shaped into any desirable form such as that illustrated in Fig. 10. In this view the copper backing has been turned down and a threaded shank 29 provided thereon; this shank being threaded into a copper electrode 31.

Previous to mounting the composite target in the electrode 31, it is desirable to first reduce the thickness of the thorium or uranium button, inasmuch as these metals must

be very thin since their heat-conductivity is low as compared to copper and the amount of heat which flows through a plate thereof under a given temperature difference between its faces is inversely proportional to the thickness of the plate.

The quantity of heat which flows through the plate can be expressed by the following equation:

$$H = \frac{KA(T_1 - T_2)}{d}$$

K=Thermal conductivity of the material;  
A=the effective area of focal spot;  
T<sub>1</sub>=the temperature of hotter side of plate;  
T<sub>2</sub>=the temperature of the cool side of plate;

d=the thickness of the plate.

In the case of a thorium X-ray target button in copper "H", which is the quantity of heat flowing through the button, should be as large as possible. The surface area of the button is practically limited by the size of the focal spot. Letting T<sub>1</sub> correspond to the melting point of thorium and T<sub>2</sub> the melting point of copper, K being a constant for thorium, then the only factor which can be varied is "d", that is the thickness of the thorium. Substituting the values for these factors, that is the values for the melting point of thorium, copper, and a constant for thorium, as well as the effective area of the focal spot, it will be found that the thickness "d" in order to obtain the maximum quantity of heat which may flow through the plate of thorium should be made at least as small as .015" or less. The foregoing explanation is made with reference to the thickness of the focal spot in order to emphasize the importance of making the thorium focal spot as thin as is mechanically possible and practical under normal usage.

The power which can be dissipated at the focal spot is limited by the thermal conductivity of the metal, at the focal spot, when the target is one having a heat capacity large enough so that the average temperature rise of the target is small in comparison with that of the focal spot, after a single exposure of short duration. The metal at the focal spot can be melted before the rest of the target has risen in temperature any appreciable amount. The temperature of the focal spot fluctuates with fluctuations of the voltage. The average power which can be dissipated by a target depends upon the form of the voltage applied to the tube. The greatest average power can be dissipated when the tube is supplied with uniform continuous voltage. In most X-ray machines the voltage is pulsating or intermittent and it is the power during a single pulse and not the average power which must be considered in designing an X-ray target.

It has been found that tantalum as well as molybdenum wets thorium and uranium so that when these metals are melted upon a

sheet of tantalum or molybdenum they will be firmly united thereto and form an intimate bond therewith.

The tantalum should be pure, which is also true of the thorium. Care should be exercised to see that the materials employed in making the target are substantially gas-free, this being particularly true with respect to the copper, for if the copper contains appreciable quantities of gases, they will come out during the fusion of the copper and the tantalum and result in blow holes and contamination of the tantalum, thus preventing the formation of an intimate bond between these metals.

Although the composite target illustrated in Fig. 10 is composed of an electrode 31 into which the composite target is inserted, it is obvious that an entire shank of solid copper 32, such as illustrated in Fig. 11, may be formed by simply enlarging the size of graphite crucible 25 in which the copper is melted and joined to the tantalum.

Another modification of the invention is illustrated in Fig. 12 in which the thorium or uranium button is united to a large mass of tantalum 33 which latter may be provided with a threaded shank 34 which in turn may be screwed into a copper rod 35.

The advantage of using tantalum or molybdenum or a similar material as an intermediate bonding material has been set forth above. To reiterate, this advantage resides in the satisfactory bond which these metals make with both thorium or uranium and copper. It is preferable to use tantalum as an intermediate bonding material as more satisfactory results have been obtained by use thereof, although molybdenum has been employed for such purposes. It might seem that where the intermediate bonding material such as tantalum or molybdenum is employed that owing to the fact that these metals have a co-efficient of expansion which is lower than either of the metals to which it is united, that the same would not firmly adhere to these metals when the target is heated and cooled. It has been found, however, in actual practice that no separation takes place between these metals and that the firm contact is maintained so that the heat conductivity at all times remains unimpaired.

As explained above, the steps actually followed in producing the composite body forming the subject of this invention involve two separate heat-treatments to join the thorium or uranium to the tantalum backing, it being apparent that this was essential in view of the fact that the first heat-treatment resulted in the thorium or uranium taking the form 19 shown in Fig. 4. However, it is thought that this second heat-treatment can readily be eliminated by previously shaping the button so that the upper surface thereof is concave, similar in appearance to that shown in

Fig. 5, thus providing for uniform shrinkage through the mass of thorium or uranium metal. As explained previously, the concavo-convex form or shape of the thorium or uranium illustrated in Fig. 4 is a result of the metal at the center of the button shrinking away from the tantalum bonding material. By previously shaping the thorium or uranium button, as above explained, the shrinkage may be made to take place in a more uniform manner with the result that the second heat-treatment may be eliminated.

Modifications of the present invention may occur to those skilled in the art, however, such modifications are contemplated as fall within the scope of the present invention as defined by the appended claims.

What is claimed is:

1. A composite target for X-ray tubes and the like comprising a button of a rare refractory metal of high atomic weight, totally fused to a backing material, the heat-conductivity of which is at least as good as that of copper.
2. A composite X-ray target comprising a thorium button intimately united to tantalum.
3. A composite X-ray target comprising a fused thorium insert intimately united to tantalum, said tantalum being intimately united to a backing material of good heat-conductivity.
4. A composite X-ray target comprising a backing material, the heat-conductivity of which is at least as good as that of copper, having welded thereto a dense coherent body of thorium.
5. A composite body for X-ray tubes comprising a backing material of good heat-conductivity having welded thereto a thin disk of thorium, the thickness of said disk being not greater than about .015 of an inch.
6. An X-ray target comprising a backing material of good heat-conductivity and of large mass, an intermediate bonding material of tantalum of relatively small mass and a button of good X-ray emitting material welded to said intermediate bonding material.
7. An X-ray target comprising a button of thorium welded to a backing material of tantalum.
8. An X-ray target comprising a large mass of copper and a button of thorium, the copper being joined to the thorium by tantalum as an intermediate bonding material.
9. The method of manufacturing composite X-ray targets employing a button of a metal of high atomic weight which comprises joining said metal to an intermediate bonding material which is wet by the button material and then melting copper in a vacuum to the intermediate bonding material.
10. The method of uniting thorium to cop-

per to form a composite X-ray target which comprises fusing thorium to tantalum and thereafter melting copper in a vacuum to the tantalum.

In testimony whereof, we have hereunto subscribed our names this 15th day of January, 1926.

JOHN WESLEY MARDEN.  
CLAYTON TRIDLE ULREY.  
LOUIS F. EHRKE.

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