

[54] **ROTATING X-RAY TARGET WITH TOOTHED INTERFACE**

[75] Inventors: **Ronald D. Konieczynski**, Royalton, Ohio; **Allan H. Springmeyer**, Newtown, Conn.

[73] Assignee: **General Electric Company**, Milwaukee, Wis.

[22] Filed: **May 11, 1973**

[21] Appl. No.: **359,459**

[52] U.S. Cl. **313/330, 313/60, 313/352, 29/182.2**

[51] Int. Cl. **H01J 35/10**

[58] Field of Search **313/60; 313/330**

[56] **References Cited**

UNITED STATES PATENTS

1,132,442 3/1915 Clawson 313/330

3,710,170 1/1973 Friedel 313/60

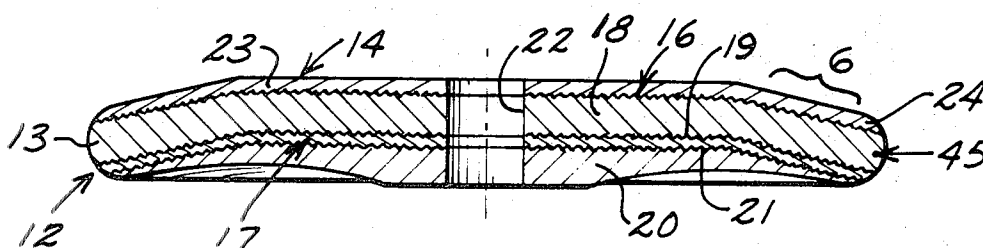
Primary Examiner—John Kominski

Assistant Examiner—Darwin R. Hostetter

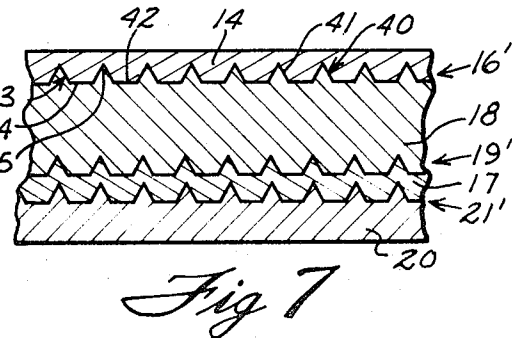
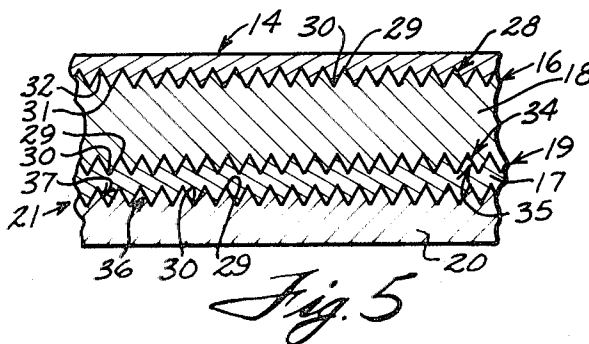
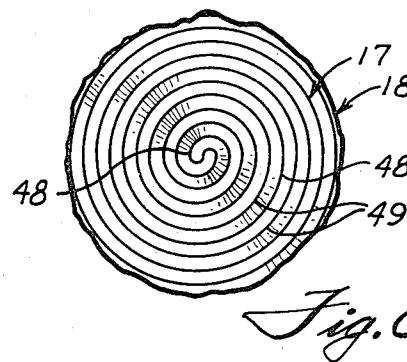
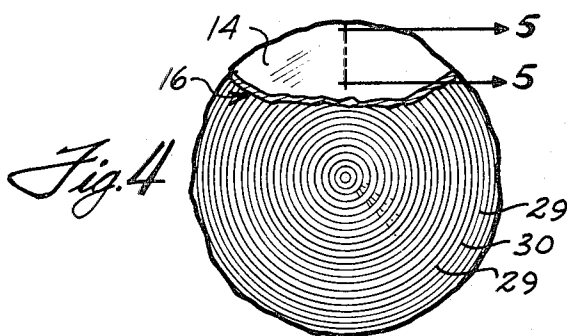
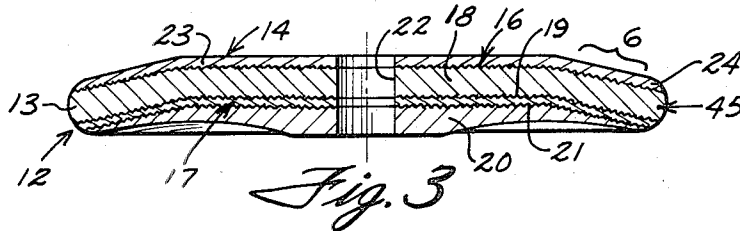
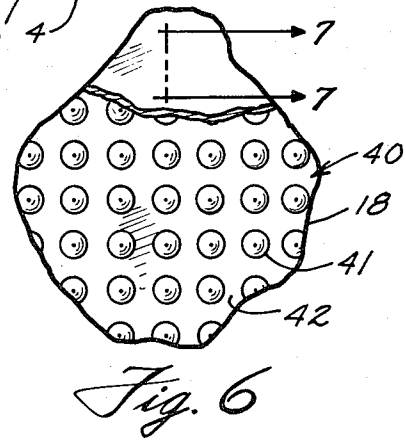
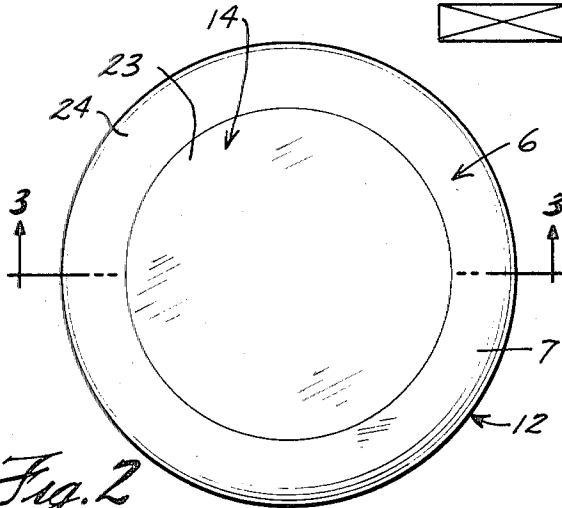
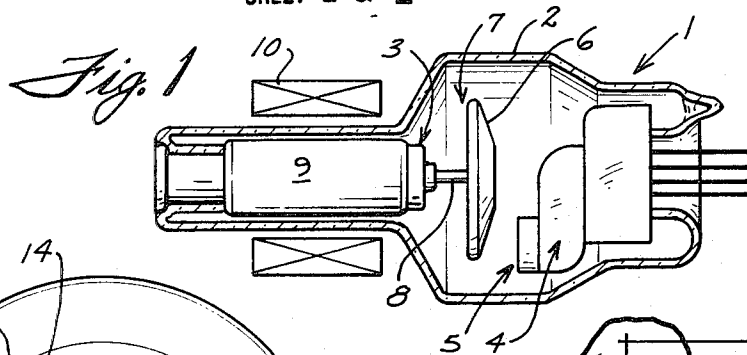
[57] **ABSTRACT**

A rotating X-ray target with an improved interface of a toothed configuration including serrations in the form of hills and valleys and in a regular pattern between one or more layers of the materials forming the target. Use of the serrated configuration at the interface between the target layer and the body provides a stronger bond between the two, a more uniform layer and prolongs the useful life of the target by resisting cracking and deformation of the focal track as well as resisting weakening of or separation of the bond between the target layer and the body.

10 Claims, 12 Drawing Figures



SHEET 1 OF 2



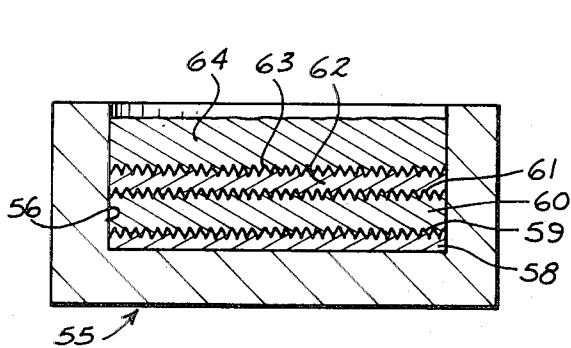


Fig. 10

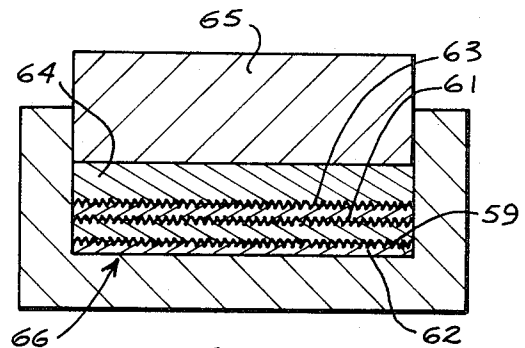


Fig. 12

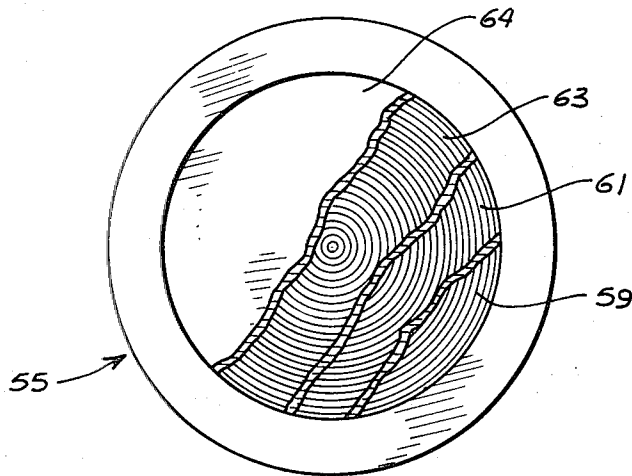


Fig. 11

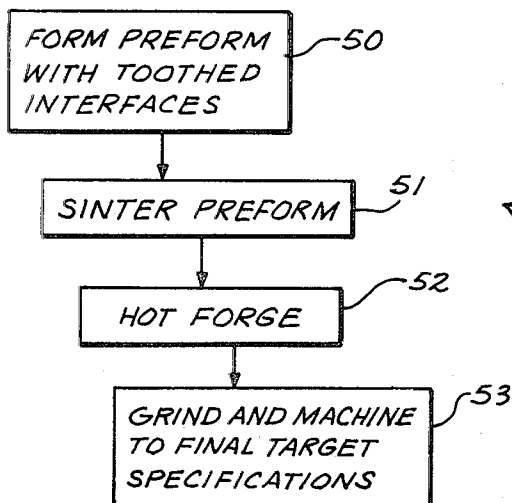


Fig. 9

ROTATING X-RAY TARGET WITH TOOTHED INTERFACE

BACKGROUND OF THE INVENTION

The invention relates to a rotating X-ray tube target with a refractory material body and a target layer of an X-ray emitting material joined to the body along a toothed interface which virtually eliminates separation of the target layer from the body. The toothed interface can also be used to enhance the bond between the body material and a warpage resisting reinforcement embedded in the body. The toothed interface eliminates separation of the target layer and/or reinforcement from the body. Exceptional resistance to cracking of the electron bombarded target face or focal track is also obtained.

Tungsten alone or tungsten alloyed with other metals are commonly used in X-ray targets. Metals which are sometimes alloyed with the tungsten are small amounts of for example, rhenium, osmium, irridium, platinum, technetium, ruthenium, rhodium, and palladium. X-ray targets formed wholly from tungsten alone, or tungsten alloys where tungsten is the predominant metal are undesirable because of the high density and weight of the tungsten. In addition, tungsten is notch sensitive and extremely brittle and is thereby subject to catastrophic failure with resultant damage to the usually delicate equipment with which the target is used, and possible injury to the patient or personnel using the equipment.

Because of the shortcomings of targets wholly of tungsten or tungsten alloys which contain relatively expensive alloying elements, attempts have been made to use tungsten or tungsten alloys as the target layer of the target and to use other materials of lower density such as molybdenum or molybdenum alloys for the body of the target. Some difficulties have been experienced with such X-ray targets because there is a tendency for the target face or focal track which is bombarded by electrons to shrink or expand differently from the substrate body material. As a result, cracks can occur in the target face portion of the target layer. The consequence of the formation of cracks in the target face is diminished efficiency of X-ray emission and erratic X-ray emission.

Rotating X-ray targets are commonly formed by powder metallurgy techniques where metal powder to form the target layer is placed against metal powder to form the substrate body and the resulting powder mass is pressed, sintered, and then forged and machined to form the target. It has recently been found desirable to incorporate within the body a reinforcement in the form of a thin layer of a high strength material such as tungsten or a tungsten alloy. As a result of the operations for forming the target from metal powder, the several layers of the target are joined to each other along an interface where some alloying of the layers usually occurs.

As a result of the electron bombardment of the focal track of the target layer, separation or weakening of the bond between the target layer and the substrate body can occur especially in the region of the annular target face or focal track. Such separation or weakening of the bond between the target layer and the substrate body results in cracking and deformation of the electron bombarded target face with adverse effects on the x-ray emission characteristics of the target face. The unequal heating of the target face and body coupled

with the centrifugally produced stresses when the target is rotated at high speed have, in the past, caused such separation and weakening of the bond between the target layer and body with resultant cracks and deformation of the target face and in some cases, actually resulting in all or part of the layer flaking off.

ADVANTAGE OVER PRIOR ART

It has been found that an improved bond, believed to be both mechanical and metallurgical, due to the greater surface areas in contact between the target layer and the substrate body as well as between the body and a reinforcement embedded in the body vastly improves the service life of rotating x-ray targets. In accordance with this invention, an x-ray target is provided which has an improved interface, toothed in a regular pattern, to enhance the bond between the body and layers of different material on or within the body such as target layers and reinforcements. The toothed interface also provides for excellent heat transfer between the body and the layer or layers of other material so the effects of localized heating, especially at the focal track, are minimized.

The invention also relates to a method of manufacturing a target having the improved interface. In the preferred method, the toothed interface is obtained by providing a plurality of serrations or hills and valleys in the powder metal used to form either the body or the target layer, and powdered metal of another layer of the target is then spread over the toothed layer so it has a mating surface configuration. Then, when the target is further formed by pressing, sintering, and swaging, a toothed interface results which provides superior resistance to separation and distortion and which has excellent heat transfer characteristics.

While a regular pattern of serrations of any desired configuration are suitable, it has been found in accordance with this invention, that a pattern of concentric circles, a regular pattern of pin holes or indentations, and a spiral pattern all provide excellent results.

SUMMARY OF THE INVENTION

The invention relates to a rotary X-ray tube target having an improved interface including a toothed hill and valley configuration at the interface, in a regular pattern, and to a method of making the target by powder metallurgy techniques. The improved interface can be used to advantage wherever a strong bond with good heat transmitting characteristics is required between layers of the material of a rotating X-ray target.

Correspondingly, it is an object of this invention to provide an improved rotating X-ray target of layered construction in which at least the focal track portion of a target layer of refractory metal is secured to a body of the target along a toothed interface having a predetermined pattern of hills and valleys.

Another object is a rotating X-ray target in which a toothed interface of a predetermined pattern of curved hills and valleys forms the interface between two different materials from which the target is formed.

A further object is a rotating X-ray tube target in which a regular pattern of indentations forms the interface between two different metals forming the X-ray target.

A further object is a unique method of forming a rotating X-ray target of layered construction in which one

or more interfaces between layers have a predetermined pattern of serrations or hills and valleys.

Numerous other objects, features, and advantages of the invention will become apparent with reference to the drawings which form a part of this specification and in which:

FIG. 1 is a view in side elevation, and partly in section of an X-ray tube showing the improved rotating X-ray target of this invention;

FIG. 2 is a top plan view of the rotating X-ray target of this invention;

FIG. 3 is a side view in section taken along line 3—3 of FIG. 2;

FIG. 4 is an enlarged partial view in plan with a major portion of the target layer removed to show the configuration of the hills and valleys at the interface of one embodiment of the rotating X-ray target of this invention;

FIG. 5 is an enlarged view in section taken along line 5—5 of FIG. 4;

FIG. 6 is a view corresponding to FIG. 4 and showing another embodiment of the hills and valleys at the interface of a rotating X-ray target of this invention;

FIG. 7 is a side view in section taken along line 7—7 of FIG. 6;

FIG. 8 is a view corresponding to FIG. 4 and showing another embodiment of the hills and valleys at the interface of a rotating X-ray target of this invention;

FIG. 9 is a block diagram showing the basic steps of the method of making the rotating targets of this invention;

FIG. 10 is a side view in section of a die or form used in the manufacture of a green preform, and illustrates the manner in which a preform is layered from powdered metals;

FIG. 11 is a top plan view of the die of FIG. 10 with layers of powdered metal partly removed to show the configuration of the interfaces; and

FIG. 12 shows the manner in which the powdered metal layers are pressed to form the green preform.

Referring now to the drawings in detail and particularly to FIG. 1 there is shown an X-ray tube 1 having a glass envelope 2 within which an anode 3 and a cathode 4 are located. The cathode 4 includes the usual electron emitting and concentrating member 5 in generally opposed relation to a target face or focal track 6 of a rotating target 7 of anode 3. The glass envelope 2 of the X-ray tube is sealed in the usual manner and has a high vacuum within the envelope. A stem 8 connects target 7 to a rotor 9 which can be rotated electromagnetically by energizing a coil 10 shown outside envelope 2, but which can also be located within the envelope, as is well known in the X-ray tube art.

With reference to FIGS. 2 and 3, target 7 has a circular periphery 12 which can be rounded or radiused as at 13. The target is composed of a target layer 14 metallurgically bonded to an intermediate layer 18 of a body 15 along an interface 16. The body 15 includes a reinforcement layer 17 which is metallurgically bonded to the intermediate layer 18 of the body along an interface 19 and to a rear outer layer 20 of the body along an interface 21. The body 15 can have a central bore or opening 22 to facilitate securing stem 8 to the target, in the well known manner.

The target face layer includes an inner generally circular or disc shaped portion 23 and an outer frustoconical portion 24, the surface of which forms the target

face 6 which is bombarded by electrons from the electron emitting member 5 of the X-ray tube.

Target 7 can be formed by powder metallurgy techniques where layers of metal powder to form the target layer 14, intermediate layer 18, reinforcement layer 17, and outer layer 20, are placed in a suitable form, pressed, and then sintered so the target layer 14 becomes bonded to the body 15 along the interface 16 and the reinforcement layer 17 becomes bonded to the body along the interfaces 19 and 21.

In accordance with the invention, improved interfaces between the target face and body as well as between the reinforcement and body strengthen the bond at the interface, virtually eliminate separation of the layers at the interface when the target is in use under high temperature conditions and at high speed, and substantially reduce cracking of the target face which is exposed to electron bombardment.

This is accomplished by toothing, serrating, or otherwise forming a predetermined pattern of hills and valleys in, for example, the target layer, while this layer is still in powder metal form, and then spreading the desired thickness of powdered metal for intermediate layer 18 of the body over the hills and valleys so the powdered body metal fills all the valleys and covers all the hills. The surfaces of either the powdered metal forming the body layers or the powdered metal forming the reinforcement layer are serrated or toothed in the same manner to enhance the bond between these layers as well as the heat transfer between the layers.

FIG. 4 shows a first embodiment of the toothed hill and valley configuration at an interface. In FIG. 4 target layer 14 is cut away so a substantial portion of the surface 28 of the layer 18 of the body is exposed. As shown at FIGS. 4 and 5 surface 28 has a plurality of concentric hills or projections 29 with valleys 30 between the hills. The hills and valleys of intermediate layer 18 mate respectively with the hills 31 and valleys 32 of target layer 14. With the target in the position of FIG. 5, each valley 30 is V-shaped and each hill 29 has an inverted V-shaped peak. The mating hills and valleys form the interface 16 between target layer 14 and intermediate layer 18 of the body. The interface 16 can be serrated or toothed across its entire width from a location adjacent the periphery 13 of the target to a location adjacent its center.

At the interface 19 between an upper surface 34 (with the target in the position of FIG. 5) of reinforcement layer 17 and a lower surface 35 of intermediate layer 18, a toothed configuration including hills and valleys 29 and 30, the same as at interface 16, can be provided. Similarly, at the interface 21 between the lower surface 36 of reinforcement 17 and the upper surface 37 of outer body layer 20 the interface can be provided with hills 29 and valleys 30, the same as at interface 16.

FIG. 6 shows a second embodiment of a configuration of hills and valleys which improve the characteristics of an interface. As shown at FIGS. 6 and 7, the top surface 40 of intermediate layer 18 of the body has a plurality of conical projections 41 projecting upwardly to form the hills, and the flat spaces 42 between the projections 41 form the valleys. As shown at FIG. 7, at the interface 16', conical projections 41 of the surface 40 are covered with the material of target layer 14 which has a mating surface 43 composed of hills 44 and valleys 45 with the valleys 45 being conical depressions

or craters in the plateau of hills 44. The interface 19' between intermediate layer 18 and reinforcement layer 17 is identical to interface 16', and interface 21' between reinforcement layer 17 and outer layer 20 is also identical to interface 16'.

FIG. 8 shows another hill and valley configuration which can be used at the several interfaces. As shown at FIG. 8 the top surface 47 of intermediate layer 18 has a spiral configuration which includes a continuous peak 48 with valleys 49 on each side of the peak. The peak 48 originates at a location adjacent the center of the target and spirals outwardly to a location adjacent the periphery of the target. The configuration of the hills and valleys is the same as the configuration of the hills and valleys seen at FIG. 5 when the interface of the embodiment of FIG. 8 is viewed in transverse section.

In the several embodiments of FIGS. 1-8, target layer 14 is made from a tungsten-rhenium alloy containing 5 percent rhenium, body sections 18 and 20 are made of molybdenum, and reinforcement 17 is tungsten. Target layer 14 is 1/64-1/8 inch thick and reinforcement layer 17 is 1/32-1/8 inch thick and the thickness of the target is 9/16 inches. In the embodiment of FIGS. 4 and 5 the distance between the peaks of hills 29 is approximately 0.02 inches and the height of each hill as measured from the plane of its flanking valleys is approximately 0.01 inches. In the embodiment of FIGS. 6 and 7, the conical hills 41 have a height of approximately 0.01 inches and a base diameter of approximately 0.01 inches with a spacing between centers of the projections of approximately 0.020 inches. In the embodiment of FIG. 8 the height of hill or peak 48 is 0.01 inches, and the distance between the bottoms of its flanking valleys 49 is 0.02 inches.

The various heights and widths of hills and valleys will depend to a certain extent on the thickness of the layers adjacent the interface. It has been found that hills in the range of 0.005 - 0.1 inches with spacings or widths on the order of 0.01 - 0.2 inches can be used depending on the thickness of the layers adjacent the interfaces.

Target layer 14 can also be tungsten, but is preferably an alloy of tungsten containing, by weight, 0.05 to 25 percent of one or more alloying metals selected from the group consisting of rhenium, osmium, irridium, platinum, technetium, palladium, ruthenium and rhodium. The body can be made of molybdenum or an alloy of molybdenum containing, by weight, 0.05-10 percent of one or more alloying metals selected from the group consisting of tungsten, tantalum, titanium, and zirconium.

METHOD OF MANUFACTURE

FIG. 9 shows the steps 50-53 for forming the target of this invention. Step 50 includes forming a preform with toothed interfaces, sintering the green preform as shown at 51, hot forging the preform to compact the layers and enhance the workability and finally, truing and machining to form the finished target of FIG. 3.

Step 50 will now be explained in detail. As shown at FIGS. 10-12, a die or form 55 has a cavity 56. First, a layer of powdered target metal is spread across the bottom of the die to form a target layer 58. The still exposed major surface 59 of layer 58 is toothed or serrated in any of the patterns of FIGS. 4, 6, or 8. This can readily be accomplished with a serrating tool having a diameter approximating the diameter of cavity 56 and

with a face having the hill and valley configuration shown at FIGS. 4, 6 or 8. The tool is merely pressed into the surface 59 to form the desired imprint. Next, powdered metal is spread over surface 59 in cavity 56 to form a layer 60 which can be a body layer. The layer is first smoothed to uniform thickness and its then exposed major surface 61 is toothed or serrated in the same manner explained for the surface 59. Then, another layer 62 of powdered material (reinforcing material) is spread over surface 61 of layer 60 and its then exposed major surface 63 is toothed or serrated in the manner explained for surfaces 59 and 61. Finally, a layer 64 of powdered body metal is spread over surface 63 to complete the layer build-up.

As shown at FIG. 11 the surfaces 59, 61, and 63 can each have the same serrated configuration. Alternatively, surface 59 can be provided with the concentric groove configuration shown at FIG. 4, surface 61 can be provided with the conical depression configuration shown at FIG. 6, and surface 63 can be provided with the spiral impression configuration shown at FIG. 8. Any desired one of these configurations can be used to advantage at desired interfaces of the target.

After the layers 58, 60, 62, and 64 of powdered metal are placed in die 55, a press block 65 which is a close fit in cavity 56 is inserted in the die and substantial pressure is applied to compress the powder layers to form a disc shaped green preform 66. This preform is sintered at a high temperature in the desired atmosphere, is hot forged, and is then ground and machined to its final target specifications.

Of the various layers of powdered metal placed in the mold of FIG. 10 it is preferred that target layer 58 be a tungsten alloy powder of a particle size in the range of 2 to 10 microns and consisting of tungsten alloyed with 5 percent by weight of rhenium. The target layer 58 can also be a fine particle size powder layer consisting of tungsten alone, or an alloy of tungsten containing, by weight, 0.05 to 25 percent of one or more alloying metals selected from the group consisting of rhenium, osmium, irridium, platinum, technetium, palladium, ruthenium, and rhodium.

Body layers 60 and 64 are preferably of powdered molybdenum of a particle size in the range of 2 to 10 microns, but can be powdered molybdenum containing, by weight, 0.05-10 percent of one or more alloying metals selected from the group consisting of tungsten, tantalum, titanium, and zirconium.

Reinforcement layer 62 is preferably powdered tungsten of a particle size in the range of 2 to 10 microns but can be a powdered metal consisting of tungsten alloyed with up to 25 percent molybdenum by weight or tungsten alloyed with up to 10 percent rhenium. Powdered metal consisting of tungsten alloyed with 5-25 percent molybdenum, or alloyed with 0.5-10 percent rhenium is preferred. Up to 5 percent by weight of metals selected from the group consisting of osmium, tantalum, titanium and zirconium can be added to the tungsten, tungsten-rhenium, or tungsten-molybdenum alloys of the reinforcement to obtain the required strength and warp resisting characteristics for the finished target.

The step of pressing the green preform with plunger 65, as shown at FIG. 12, is accomplished by applying a force to the plunger sufficient to exert a pressure on the powder in the dye of 25,000 pounds per square inch or more. Pressures of this magnitude compact the pow-

der in the dye to form the green preform 66. During the step of sintering, the green preform 66 is heated to elevated temperatures in the range of 3,800°F – 4,500°F. Next the preform is hot forged to further compact the sintered powder layers forming the target. During the heating and sintering some alloying occurs between the layers so the interfaces are securely bonded together. During forging, a die with a configuration conforming generally to the configuration of the front face of the target is used so a frustoconical focal track is formed. During forging, the entire target blank including the reinforcement layer 62 is deformed so its outer portion becomes frustoconical and is generally parallel with focal track 6 of the target layer.

Next, the sintered and forged target blank is ground and machined to its final specifications.

Targets manufactured in accordance with the procedure described showed prolonged life over targets of similar compositions, but without the toothed interface between the target layer and the body. Exceptional resistance to cracking and distortion of the target face or focal track of the target was observed. Separation between the reinforcement and the body in any of the toothed interface targets was virtually eliminated.

It is to be understood that the target shown at FIG. 3 in which target layer 14 extends across the entire face of the target and in which reinforcement layer 19 extends the entire width of the target, is merely exemplary of a target construction using the unique toothed interface arrangement of this invention. The toothed interface arrangement disclosed and described herein can also be used to advantage with any of the several embodiments of target disclosed in our copending application entitled WARPAGE RESISTING X-RAY TARGET AND METHOD OF MANUFACTURE, filed Apr. 11, 1973.

While several preferred embodiments of an improved rotating x-ray target according to this invention have been shown and described, and while several preferred methods of forming the improved rotating target have also been shown and described, it is to be understood that numerous changes can be made without departing from the scope of this invention as set forth herein and defined in the appended claims.

What is claimed is:

1. An x-ray tube rotary target comprising, in combination,
 - a refractory metal target face; and
 - a refractory material body joined to the target face by powdered metallurgy technique along an interface to form a unitary structure;
 - the interface including a multiplicity of mating hills

and valleys in a predetermined pattern in the body and the target face.

2. An X-ray tube target according to claim 1 wherein the multiplicity of hills and valleys include continuous curved projections and grooves in the body and target face at the interface.

3. An X-ray tube target according to claim 2 wherein the projections are V-shaped; and the grooves are V-shaped and mate with the projections.

4. An X-ray tube target according to claim 2 wherein the projections include a plurality of concentric circular projections; and the grooves are concentric and circular and mate with the projections.

5. An X-ray tube target according to claim 1 wherein the multiplicity of hills and valleys include a multiplicity of distinct spaced apart depressions and projections.

6. An X-ray tube target according to claim 5 wherein the projections are conical, and the depressions are conical and mate with the projections.

7. An X-ray tube target according to claim 1 wherein the refractory metal target face is predominantly tungsten, the refractory material body is predominantly molybdenum, and the tungsten and molybdenum are alloyed at the interface.

8. An X-ray tube target according to claim 1 wherein the hills are each of the same height in the range of 0.005–0.10 inches, and each of the same width in the range of 0.010–0.20 inches; and the valleys mate with the hills.

9. An X-ray tube rotary target according to claim 1 wherein

the target further includes

a reinforcement layer of metal within the body and joined to the body along additional interfaces; the additional interfaces including a multiplicity of mating hills and valleys in a predetermined pattern in the reinforcement and the body.

10. An X-ray tube rotary target according to claim 9 wherein

the refractory metal target face is predominantly tungsten;

the refractory body is predominantly molybdenum; and

the reinforcement is predominantly tungsten.

* * * * *

55

60

65