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[73] Assignee **Sylvania Electric Products Inc.**

[54] **APPARATUS AND METHOD OF METAL EVAPORATION INCLUDING AN EVAPORATION BOAT HAVING LOWER ELECTRICAL RESISTIVITY ENDS THAN THE CENTER THEREOF**
7 Claims, 2 Drawing Figs.

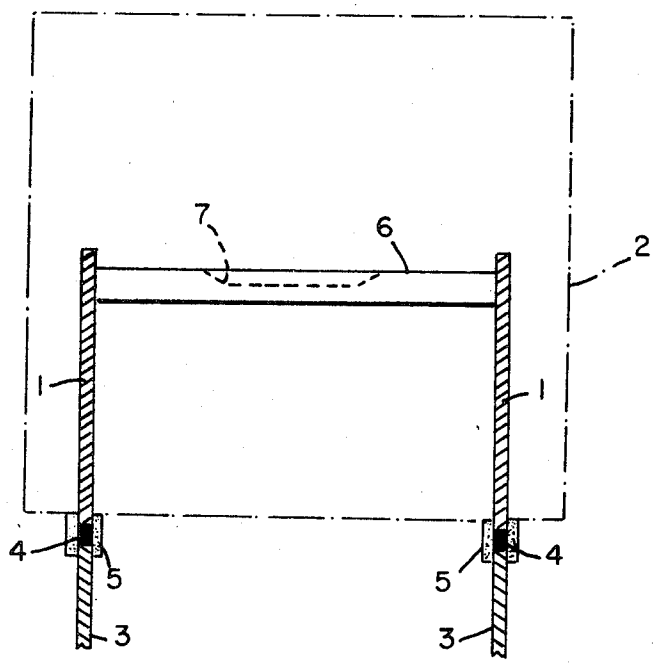
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[51] **Int. Cl.** **F22b 1/28**
[50] **Field of Search** 219/271, 272, 275, 538, 548, 552; 13/25; 117/107, 107.2R; 118/48, 49, 49.1, 620; 252/520; 338/223, 224, 330

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ABSTRACT: In an apparatus for evaporation and vacuum deposition of metal on an article to be coated therewith, spaced-apart electrical binding posts are located within a vacuum chamber. The ends of an electrical self-resistance-heated evaporation boat are clamped to the binding posts. The end portions of the boat have a lower electrical resistivity than the center portion in order to minimize contact resistance and to reduce power dissipation at the ends of the boats.



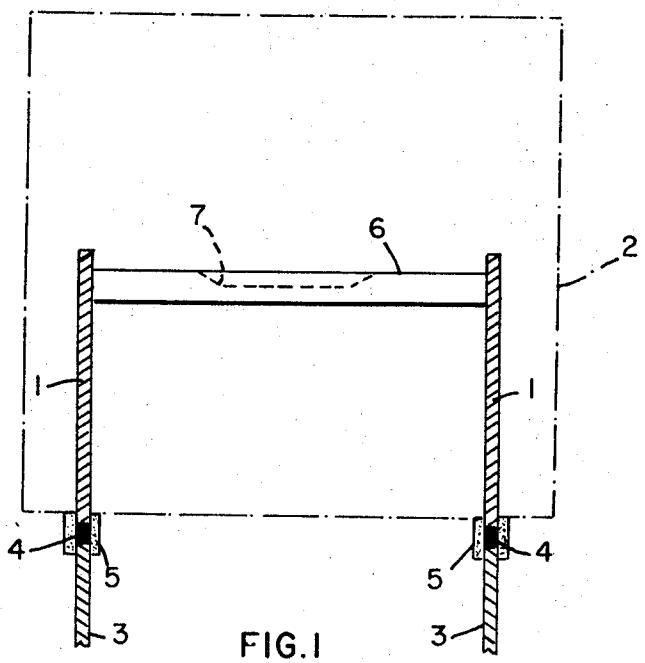


FIG. 1

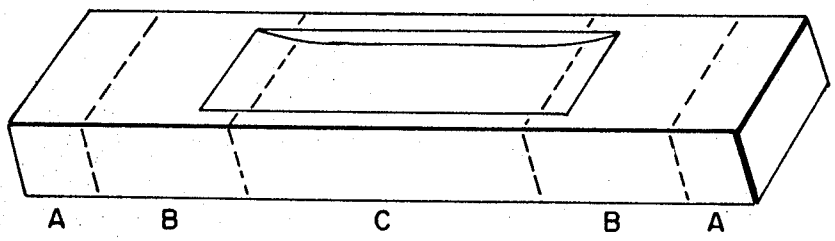


FIG. 2

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APPARATUS AND METHOD OF METAL EVAPORATION INCLUDING AN EVAPORATION BOAT HAVING LOWER ELECTRICAL RESISTIVITY ENDS THAN THE CENTER THEREOF

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to the field of apparatus for the vapor deposition of metal coatings and especially to end-clamped self-resistance electrically heated boats used in such apparatus.

2. Description of the Prior Art

In the field of metal vapor deposition and especially in the continuous coating of paper or plastic film with aluminum, the coating apparatus commonly consisted of a vacuum chamber having one or more evaporation boats therein. The boats were clamped to binding posts through which electrical power was delivered thereto and the boats were electrically heated to a temperature capable of evaporating aluminum wire delivered from a spool to a cavity in the boat.

A roll of film to be coated was also mounted within the chamber, with means to pass the film above the evaporation boat and reel it up on a spool.

Such boats were commonly made of suitable electrically conductive refractory materials, such as tungsten or graphite, and usually had a protective barrier between the refractory material and the molten aluminum in order to prevent corrosion thereof by the aluminum.

Later, other electrically conductive boats were developed that were resistant to molten aluminum and, therefore, obviated the need of a protective barrier therebetween. Such boats commonly comprised a dense homogenous body that had been pressed from a blend of refractory powders that had been preselected to impart desired properties to the evaporation boat. Examples of refractory powders that were used titanium boride and boron nitride.

The electrical resistivity of all such prior art boats was substantially uniform throughout their length and was usually determined by the characteristics of the vacuum apparatus with which they were used. The resistivity had to be high enough so as to provide that most of the delivered electrical power was used in heating the boat. In addition, the resistivity should not be so high as to result in a high contact resistance between the boat and the binding posts. A high contact resistance results in excessive power loss at the ends of the boat and can also result in rapid deterioration of the electrical connection between the boat and the binding posts.

SUMMARY OF THE INVENTION

A metal-evaporating apparatus, in accordance with this invention, comprises a vacuum chamber having electrical binding posts therein and a monolithic variable-resistance evaporation boat clamped between the binding posts. The ends of the boat have a lower resistivity than the center thereof in order to reduce end heat loss and to maintain good contact connection with the binding posts.

In order to improve the operating temperature profile of the boat, there may be an intermediate region between the ends of tee boat and the center, the intermediate region having a higher resistivity than the center. Such an intermediate region of high resistivity results in a lengthened hot zone.

The boat, having regions of different resistivities throughout its length, must be essentially an integral, unitary structure in order to withstand high operating temperatures. In addition, the regions of different resistivities must have thermal coefficients of expansion that are quite similar, in order to prevent cracking or fracturing. For this purpose, the boat can be hot pressed to a dense monolithic structure from two or more blends of refractory powders. Preferably, the blends comprise essentially the same constituents, although in differing proportions or particle sizes, for the purpose of matching the thermal expansion coefficients. For example, a boat could have a center portion consisting of a blend of 50 percent titanium diboride—50 percent boron nitride and could have ends consisting of a blend of 45 percent titanium diboride—55 percent boron nitride. In such a boat, the center would have an electrical resistivity of about 1,000 microhm-centimeters and the ends would have an electrical resistivity of about 400 microhm-centimeters—or the proportion of each blend could be 50 percent titanium diboride—50 percent boron nitride, but the particle size of the boron nitride in the center of the boat could be coarser than that at the ends of tee boat, say, coarser-than-100 mesh versus finer-than-200 mesh. In such a case the respective resistivities would be about 2,400 and 400 microhm-centimeters.

In the high-current, low-voltage type of evaporation apparatus to which this invention relates, say, where the power consumption is greater than about 100 amperes at less than about 20 volts, the resistivity of the ends should be less than about 1,000 microhm-centimeters.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a drawing of an evaporation apparatus in accordance with this invention, the vacuum chamber being shown in phantom.

FIG. 2 is an enlarged drawing of the evaporation boat of FIG. 1, the letters and dotted lines indicating regions of different resistivity.

DESCRIPTION OF THE PREFERRED EMBODIMENT

As shown in the drawing, an apparatus for metal evaporation and deposition comprises two electrical binding posts **1** disposed within a vacuum chamber **2** (shown in phantom). Binding posts **1** are electrically connected to external lead-in wires **3** by means of electrical terminals **4** fastened in one wall of chamber **2**. Terminals **4** are supported and electrically insulated from the chamber wall by means of vacuumtight seals **5**. Disposed between binding posts **1**, and clamped thereto, is a variable resistance evaporation boat **6**. Power is supplied to boat **6** by connecting lead-in wires **3** to a suitable external electric power source.

A conventional vacuum pump, not shown, may be used to reduce the chamber pressure to the usual vacuum necessary for aluminum evaporation and deposition, say, about 10^{12} to 10^{15} Torr.

As shown by dotted lines in FIG. 2, boat **6**, although an integral monolithic structure, has five distinct regions having three different resistivities. Regions A are at the ends of the boat and have the lowest resistivity. Regions B abut regions A and have the highest resistivity. Region C is at the center and has a resistivity intermediate that of A and B.

Boat **6** has a cavity **7** on its upper surface for the purpose of containing the aluminum being melted and evaporated. In operation, aluminum wire is fed continuously to about the center of cavity **7**, where it rapidly melts and may flow slightly before being rapidly evaporated.

In one specific embodiment of an evaporation boat in accordance with this invention, boat **6** was made of titanium diboride, boron nitride, aluminum nitride and boric oxide in a manner to be presently described.

A refractory powder blend (blend A) consisting of 46.7 percent titanium diboride, 25.5 percent boron nitride, 27.0 percent aluminum nitride and 0.87 percent boric oxide (all percentages by weight) was loosely packed into a 5-inch-diameter cylindrical die to a height of about 2¾ inches. The blend was then cold pressed at a pressure of 1,500 pounds per square inch, which operation compressed the billet to a height of about 1¼ inches.

Another refractory powder blend (Blend B) was then loosely packed on top of the billet of Blend A to a height of about 2¾ inches and subjected to the same cold pressing operation, thereby compressing the billet of Blend B to about 1¼ inches. Blend B consisted of 40.1 percent titanium diboride, 30.4 percent boron nitride, 28.7 percent aluminum nitride and 0.88 percent boric oxide (all percentages by weight).

A third refractory powder blend (Blend C) was then loosely packed on top of the billet of Blend B to a height of about 10¾ inches and was cold pressed, at 1,500 pounds per square inch, to a height of about 4¾ inches. Blend C consisted of 40.7 percent titanium diboride, 30.3 percent boron nitride, 28.15 percent aluminum nitride and 0.87 percent boric oxide (all by weight).

An additional amount of Blend B, and then Blend A, each amount equal to that previously packed and pressed, were each added and cold pressed as before. The final cold pressed billet, consisting of the five individual billets weakly bonded together, had a height of about 9¾ inches.

This billet was then hot pressed at a temperature of 2,050° C. for four hours at a pressure of 3,000 pounds per square inch to yield a dense, monolithic structure having a compressed height of about 5½ inches. The compressed heights of the individual blends or regions A, B, C, B, A were about 11/16, 11/16, 2 11/16, 11/16 and 11/16 inches, respectively. There was no readily apparent line of demarcation between the respective regions.

Boat 6, as shown in FIG. 2, was machined from the hot-pressed billet in the longitudinal direction, so that Regions A comprised the ends of the boat, Regions B the abutting portion thereof and Region C the center. Boat 6 was 5 inches long, ½ inch thick and ¾ inch wide. Regions A, B, C, B, A in the finished boat were 15/32, 11/16, 2 11/16, 11/16 and 15/32 inches long, respectively and cavity 7 was about 3 inches long, thus extending the full length of Region C and into portions of both Regions B.

The electrical resistivity of Region A was about 500 microhm-centimeters; that of Region B was about 1,700 and Region C about 1,200.

A comparison of the instant boat with a conventional boat that had a uniform resistivity of about 1,320 microhm-centimeters throughout its length showed that the instant boat required 20 percent less electrical power to attain a peak temperature of 1,400° C. **than did the conventional boat. This result is due primarily to the low end resistance of the instant boat.**

In another example of a boat in accordance with this invention, boat 6 had only three regions of differing resistivities throughout its length. The end regions were ⅝ inch long and were prepared from a blend consisting of (by weight) 45.5 percent titanium diboride, 29.7 percent boron nitride, 24.0 percent aluminum nitride and 0.87 percent boric oxide. The center region was 5¼ inch long and was prepared from a blend consisting of (by weight) 41.1 percent titanium diboride, 30.2 percent boron nitride, 27.95 percent aluminum nitride and 0.8 percent oxide. Resistivity of the end regions was about 900 microhm-centimeters and that of the center was about 1,400 microhm-centimeters. This boat required about 10 percent less power to attain a maximum temperature of 1,400° C. than did a conventional boat having uniform resistivity.

It can be noted from the compositions of the various blends mentioned above that significant changes in the resistivities thereof can be made by only slight changes in the percentages of the individual ingredients. For example, the resistivity of Blend B is 3.4 times that of Blend A, while the differences of composition therebetween are only slight, as follows: Titanium boride—40.01 percent versus 46.7 percent; boron nitride—3.4 percent versus 25.5 percent; aluminum nitride—28.7 percent versus 27.0 percent; boric oxide—0.88 percent versus 0.81. The slight compositional differences between blends is important in that it results in coefficients of thermal expansion of the various blends being almost identical, thereby greatly reducing the likelihood of thermal stress fracture at the junction areas of the blends.

We claim:

1. An elongated boat for the evaporation of metal comprising a monolithic structure having a cavity at about its center and having ends suitable for attachment to the binding posts of evaporation apparatus, said structure comprising at least two electrically conductive blends of refractory powders, the resistivity of one blend being lower than the other and wherein said lower resistivity blend constitutes the ends of said boat and the other blend constitutes the center of said boat.

2. The apparatus of claim 1 wherein said boat comprises a dense monolithic structure of at least two blends of refractory powders.

3. The apparatus of claim 2 wherein the ends of said boat comprise a blend including titanium diboride and boron nitride and have a resistivity less than 1,000 microhm-centimeters and the center of said boat comprises a blend including titanium diboride and boron nitride and has a resistivity greater than 1,000 microhm-centimeters.

4. A method of evaporating metal including the steps of: disposing a roll of wire of said metal in a vacuum chamber; sealing said chamber and reducing the pressure therein; unwinding said roll and directing the free end of said wire into the cavity of a unitary variable-resistance evaporation boat, said boat having low resistivity ends and a higher resistivity center, the ends of said boat being clamped to electrical binding posts within said chamber; and passing sufficient electrical current through said boat to heat it to the evaporation temperature of said metal wire.

5. The method of claim 4 wherein said metal is aluminum and said boat comprises at least two blends of refractory metal powders including titanium diboride and boron nitride.

6. The boat of claim 1 wherein both of said blends comprise boron nitride and titanium diboride.

7. The boat of claim 1 wherein the resistivity of the ends of said boat is less than about 1,000 microhm-centimeters.