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APPARATUS AND PROCESS FOR COATING BY VAPOR DEPOSITION

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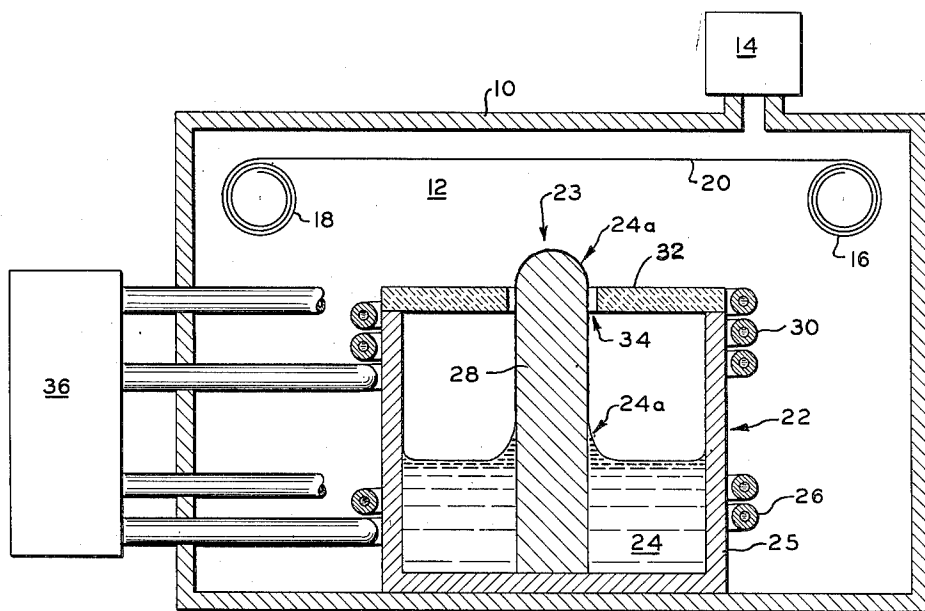


FIG. 1

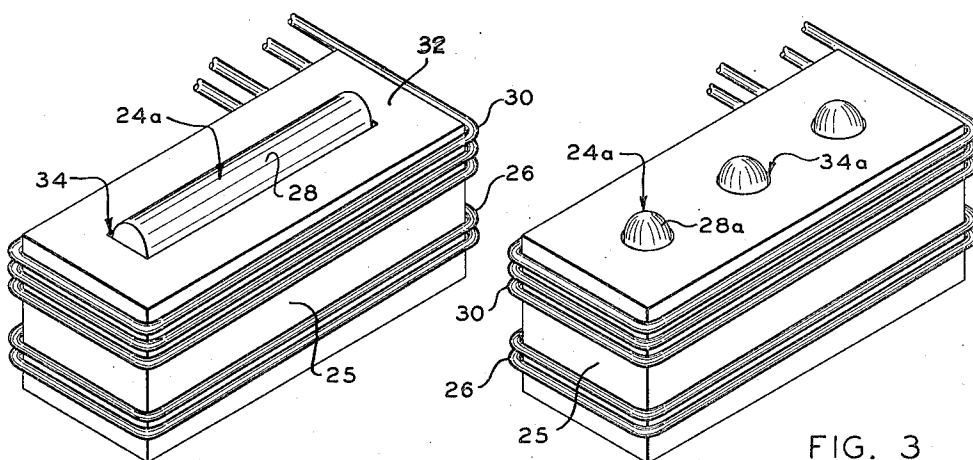


FIG. 2

FIG. 3

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APPARATUS AND PROCESS FOR COATING
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5 Claims. (Cl. 117—107)

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This invention relates to coating and more particularly to vacuum-deposition coating of the type wherein a metal, such as aluminum, is vaporized in a vacuum and the vapors thereof are condensed on a substrate which is moved past the source of the metal vapors.

This application is in part a continuation of the copending application of Chadsey et al., Serial No. 117,124, filed September 22, 1949.

In vacuum-deposition coating it is desired to have a relatively large source of the metal, such as aluminum, so that large areas of the substrate may be coated without shutting down the operation of the coating device. It is also desirable to have a relatively small evaporating area heated to a high temperature so as to decrease the amount of radiant heat which is transferred to the substrate per gram of aluminum coated on the substrate.

Accordingly, it is a principal object of the present invention to provide an improved process for the vapor-deposition coating of substrates with metals, such as aluminum, wherein a large supply of the metal is maintained in the vacuum chamber, and a relatively small percentage of the metal is heated to a high temperature to obtain a rapid evaporation thereof.

Another object of the present invention is to provide a coating process of the above type wherein a large supply of the metal is maintained at a relatively low temperature and a molten portion of the metal in the supply is caused to travel from the low-temperature supply to a high-temperature evaporation zone where it is rapidly evaporated.

Another object of the invention is to provide such a process which can be practiced with very simple forms of coating apparatus.

Still another object of the invention is to provide a coating process of the above type which permits maintaining at a minimum those heat-radiating surfaces other than the evaporating surface of the metal.

Still another object of the invention is to provide an improved apparatus which is particularly adapted for practicing processes of the above type.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the apparatus possessing the construction, combination of elements and arrangement of parts, and the process involving the several steps and the relation and the order of one or more of such steps with respect to each of the others which are exemplified in the following detailed disclosure, and

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the scope of the application of which will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings wherein:

Fig. 1 is a diagrammatic, schematic, partially sectional view of one preferred apparatus embodying the present invention;

Fig. 2 is a schematic, diagrammatic, isometric view of a portion of the apparatus of Fig. 1; and

Fig. 3 is a diagrammatic, schematic, isometric view of a modification of a portion of the apparatus shown in Fig. 1.

In the practice of the present invention, there is provided a usual vacuum-coating chamber which can be evacuated to pressures in the micron range. Associated with this chamber there is provided a low-temperature zone for confining the metal to be coated, this low-temperature zone being preferably arranged to maintain the metal in a molten pool at a temperature somewhat above its melting point.

In a preferred form of the process of this invention, the metal comprises aluminum, and for simplicity of description aluminum will be referred to hereinafter. The large body of aluminum confined in the low-temperature zone is preferably held in a container which is substantially inert to molten aluminum at relatively low temperatures on the order of 800° C. There is also provided a high-temperature evaporation zone where the aluminum may be heated to a high temperature, preferably above 1300° C. At this temperature the heat transmitted by radiation from a unit area of the evaporating aluminum surface to a unit area of the substrate is less than the heat transmitted to a unit area of the substrate by the vapors condensing thereon. For feeding the molten aluminum from the low-temperature zone to the evaporation zone, there is included a wick element which extends into the pool of molten aluminum and is wet by the molten aluminum. The aluminum, which wets the wick element, travels from the low-temperature zone to the high-temperature zone where it is rapidly evaporated. This wick element preferably comprises a material which is relatively inert to aluminum at high temperatures, and preferably comprises a nitride or a carbide. Of the carbides and nitrides, those of the group IVa and group Va metal carbides and nitrides are preferred. The wick element also preferably acts as a support for the aluminum in the high-temperature evaporation zone.

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Referring now to Figs. 1 and 2, there is shown one preferred embodiment of the invention wherein there is provided a vacuum-tight housing 10 which defines therewithin a vacuum chamber 12. Vacuum chamber 12 is arranged to be evacuated to very low pressures, on the order of one micron, by means of a vacuum pumping system, schematically indicated at 14. Within the vacuum chamber there is provided a means for supporting the substrate to be coated, this means comprising a first spool 16 and a second spool 18 carrying therebetween the substrate 20. For holding the relatively large supply of metal, there is included a low-temperature zone indicated generally at 22, while for evaporating the metal there is provided a high-temperature zone generally indicated at 23. The low-temperature zone comprises a container 25 which may be formed of carbon or the like, this container confining a large body of low-temperature molten aluminum 24. The aluminum 24 is arranged to be maintained slightly above its melting point by means of an induction heating coil 26. For feeding molten aluminum from the low-temperature zone 22 to the high-temperature evaporation zone 23, there is provided a wick element 28 which communicates between these two zones, aluminum traveling along the wick element being indicated at 24a. The upper end of wick element 28, which constitutes the high-temperature evaporation zone 23, is arranged to be heated by an induction coil 30 which preferably maintains the aluminum 24a on the surface of the wick element at a high temperature, on the order of 1300° C. or above.

For eliminating radiation from all but the tip of the wick 28, there is included a refractory shield 32 provided with a hole 34 through which the wick 28 extends into the evaporation zone. Power source 36 supplies current to the two induction coils 26 and 30.

As can be seen from Fig. 2, the wick element 28 is preferably in the form of a long plate which has a length, extending transversely of the substrate, which is approximately equal to the width of the substrate. This particular arrangement has the advantage that the upper edge of the wick 28 constitutes a line source for evaporating aluminum at a high temperature. Since this upper edge is substantially completely covered by aluminum, which wets the wick element, there is substantially no radiation of heat to the substrate other than that radiating from the evaporating surface of the aluminum 24a. Refractory shield 32 prevents radiation from the surface of the large low-temperature pool of aluminum 24, and also prevents radiation from that aluminum 24a which is climbing up the wick 28 and which is not heated to the high evaporation temperature.

In a preferred embodiment of the invention described above, the container 25 preferably comprises carbon, or a mixture of carbon and graphite, while the wick element 28 preferably comprises a carbon plate whose surface has been treated to form a carbide of a group IVA or group Va metal. One preferred method of forming such a carbide surface is to dip the plate under vacuum, into a molten bath of aluminum and zirconium, this molten bath forming a zirconium carbide surface on all portions of the carbon plate dipped into the bath. The current in the induction coil 30 is preferably of a relatively low frequency, so that the skin depth of the induced current is greater than the thickness of that por-

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tion of the carbon container 25 which is between the induction coil 30 and the wick element 28. With this arrangement, high induced currents are produced in the wick element 28 adjacent the top thereof to heat this top portion to a high temperature, on the order of 1300° C. or above.

In lieu of precoating the wick element 28, zirconium metal may be added to the aluminum 24 in the container 22, so that a zirconium carbide skin is formed on the surface of the wick element when in use. However, this system is less preferred than that wherein the wick element is first treated so as to form thereon the carbide surface. Other materials which are wet by aluminum may be utilized in place of a carbide of the group IVA and group Va metals but, for reasons of expense, they are less preferred. Additionally, it has been found that the group IVA and group Va metals are eminently satisfactory for this purpose and, of these metals, zirconium, because of its effectiveness and relative abundance, is preferred.

In the use of the Fig. 1 and Fig. 2 embodiments of the invention, the substrate 20 is mounted in the coating chamber 12, the chamber is evacuated to about one micron, and the aluminum 24 in the container 25 is heated by the coil 26 to slightly above its melting point. The top part of the wick 28 is then heated to a high temperature by means of the induction coil 30. During this heating, the aluminum 24 commences to climb, as indicated at 24a, up the surface of the wick element 28 and completely covers the upper end thereof. Since the upper end of this wick is at a high temperature, the climbing aluminum 24a is heated to an equally high temperature and evaporates rapidly, the vapors traveling to the substrate 20 where they are condensed to form a continuous shiny film of aluminum. In order to maintain a uniform thin coat, the substrate 20 is preferably moved at a speed commensurate with the amount of vapors created at the top of wick element 28. This speed is preferably adjusted to give a coating of approximately .7 gram to 30 square feet of substrate area. If desired, automatic controls of the type described in the copending application of Philip Godley 2nd, Serial No. 10,117, filed February 21, 1948, may be employed for controlling the coating thickness.

In an alternative embodiment of the invention, the high temperature evaporation zone comprises a plurality of separate zones rather than a single line zone as shown in Fig. 2. In Fig. 3 a plurality of wicks are provided, these wicks being preferably spaced transversely of the sheet, each wick coating a predetermined, longitudinal segment of the substrate as it is moved through the coating chamber. In Fig. 3, where like numbers refer to like elements of the Fig. 1 and Fig. 2 embodiments, there is provided a plurality of wick elements 28a, each wick element 28a comprising a generally cylindrical rod having a rounded top portion. In this embodiment of the invention, there is provided a plurality of holes 34a through which the upper ends of the wick element 28a extend. The Fig. 3 embodiment of the invention thus provides a plurality of point sources of aluminum vapors, these point sources being spaced transversely of the sheet so as to give a uniform coating. The materials utilized in the Fig. 3 embodiment of the invention are preferably similar to those discussed in connection with the Fig. 1 and Fig. 2 form of the invention.

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The expression "group IVa and group Va metals" is intended to include those metals in groups IVa and Va on the "Periodic Chart of the Atoms," Henry D. Hubbard, 1947 Edition, W. M. Welch Manufacturing Company.

Since certain changes may be made in the above process and apparatus without departing from the scope of the invention herein involved, it is intended that all matter contained in the above description, or shown in the accompanying drawings, shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A process for coating a substrate with aluminum by vacuum-evaporating said aluminum and condensing said aluminum on said substrate, said process comprising the steps of providing a supply of said aluminum in a vacuum chamber, evacuating said chamber, melting at least a portion of said aluminum in said supply of aluminum, providing a wick element having at least a surface stratum comprising a compound selected from the class consisting of the carbides and nitrides of titanium, zirconium, hafnium, vanadium, columbium and tantalum, confining said molten aluminum in a low-temperature pool in contact with said wick element, heating said wick element to a temperature higher than the temperature in said pool, evaporating by said high temperature that aluminum which wets said wick element, shielding said substrate from radiation emanating from the low-temperature pool of molten aluminum, and moving said substrate past said wick element to coat aluminum on said substrate.

2. Apparatus for coating a substrate with aluminum by vacuum-evaporation of said aluminum and condensation of said aluminum on said substrate, said apparatus comprising means defining a vacuum-tight chamber, a container for confining said aluminum within said chamber, means for melting at least a portion of said confined aluminum, means comprising a plurality of wick elements, said wick elements comprising at least a surface stratum selected from the group consisting of the carbides and nitrides of titanium, zirconium, hafnium, vanadium, columbium and tantalum, means for heating said wick elements to a temperature higher than the temperature of said molten aluminum, said container for confining said aluminum being arranged to maintain at least a portion of said molten aluminum in at least one pool in contact with said wick elements so that said wick elements are wet by said aluminum and said aluminum is evaporated from said wick elements by said high temperature, means comprising a radiation shield over said container, said wick elements extending from within said container to the exterior thereof and beyond said radiation shield, and means for moving said substrate past said wick elements to coat aluminum on said substrate.

3. In an apparatus for coating a substrate with

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aluminum by vacuum-evaporation of the aluminum and condensation of the aluminum vapors on a substrate, an improved source of aluminum vapors comprising a carbon container for holding molten aluminum, means comprising a radiation shield over said container, means for heating said aluminum to maintain said aluminum in molten condition, a wick element which is wettable by molten aluminum, said wick element comprising at least a surface stratum selected from the group consisting of the carbides and nitrides of titanium, zirconium, hafnium, vanadium, columbium and tantalum, said wick element extending from within said container to the exterior thereof and beyond said shield, and means for heating said wick element to a temperature higher than the temperature of said molten aluminum.

4. Apparatus for coating a substrate with aluminum by vacuum-evaporation of said aluminum and condensation of said aluminum on said substrate, said apparatus comprising means defining a vacuum-tight chamber, a container for confining said aluminum within said chamber, means for melting at least a portion of said confined aluminum, means comprising a wick element, said wick element comprising at least a surface stratum selected from the group consisting of the carbides and nitrides of titanium, zirconium, hafnium, vanadium, columbium and tantalum, means for heating said wick element to a temperature higher than the temperature of said molten aluminum, said container for confining said molten aluminum being arranged to maintain at least a portion of said molten aluminum in a pool in contact with said wick element so that said wick element is wet by said aluminum and said aluminum is evaporated from said wick element by said high temperature, a radiation shield over said container, said wick element extending from within said container to the exterior thereof and beyond said radiation shield, and means for moving said substrate past said wick element to coat aluminum on said substrate.

5. The apparatus of claim 4 wherein said wick element comprises a platelike member, one long edge of which is positioned in said pool of aluminum and the other long edge of which extends above the shield so as to be in position to radiate aluminum vapors to said substrate.

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