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P. J. CLOUGH ET AL

2,665,227

APPARATUS AND METHOD OF COATING BY VAPOR DEPOSITION

Filed June 30, 1950

3 Sheets-Sheet 1

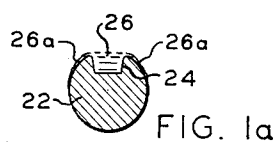
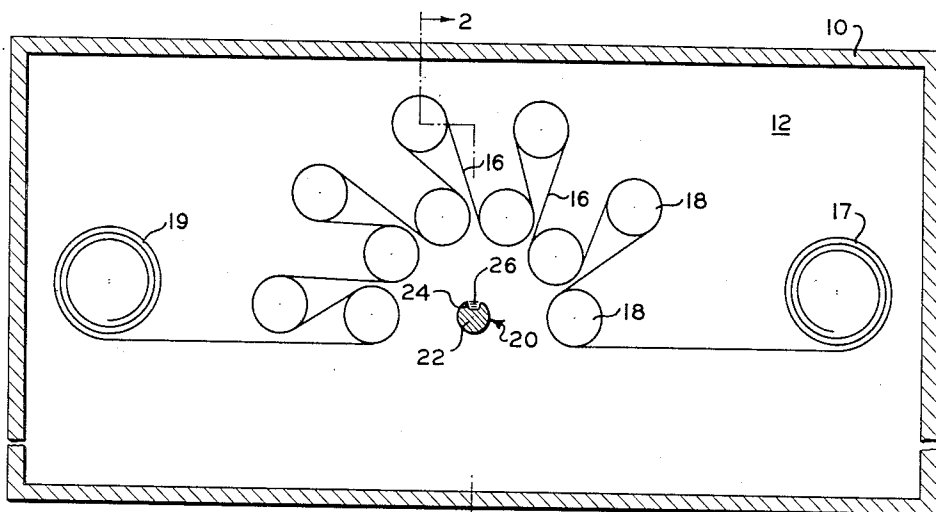


FIG. 1

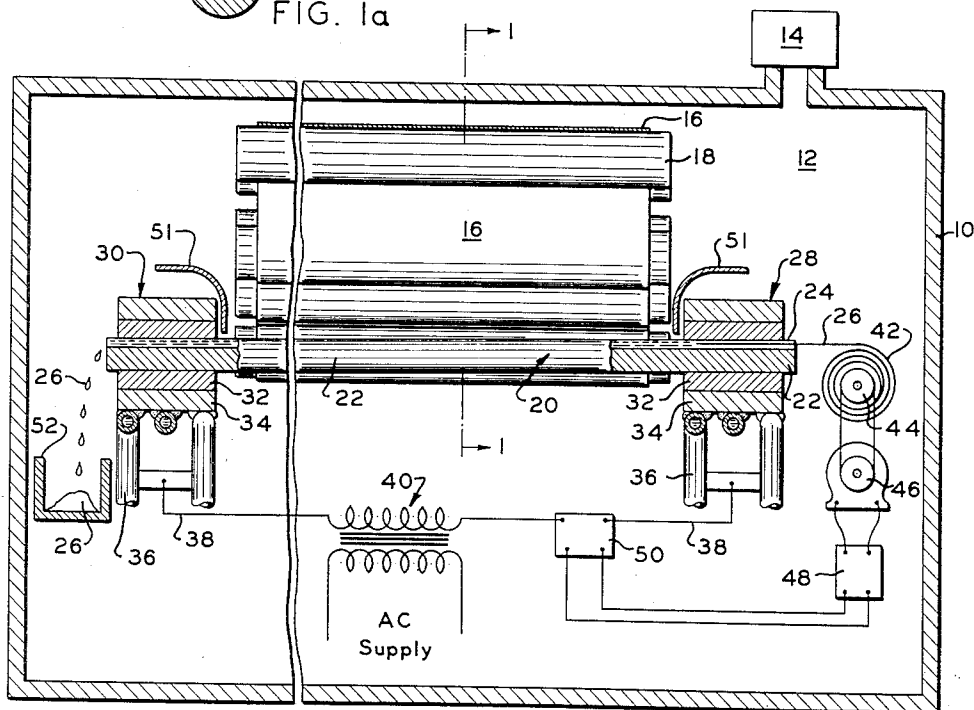


FIG. 2

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3 Sheets-Sheet 2

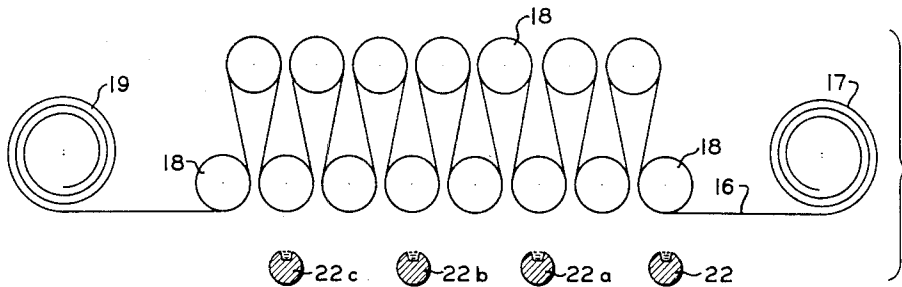


FIG. 3

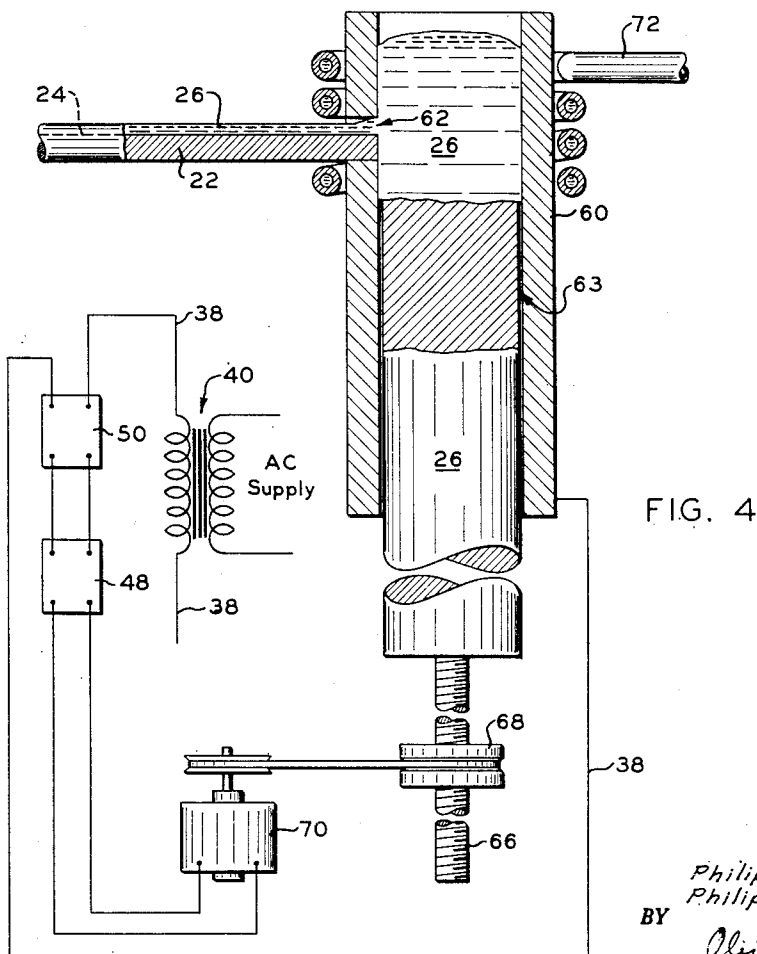


FIG. 4

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3 Sheets-Sheet 3

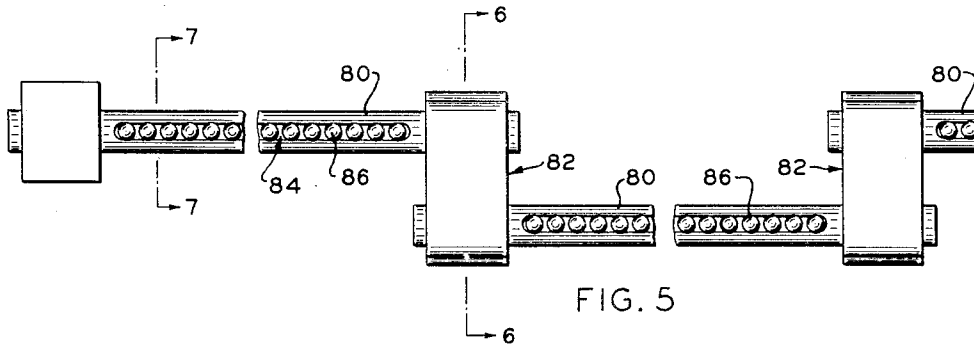


FIG. 5

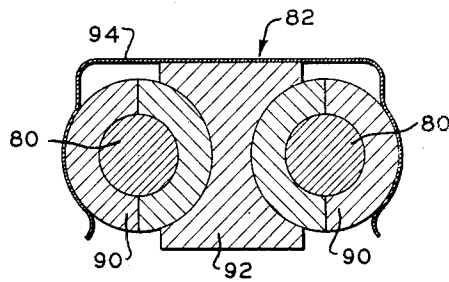


FIG. 6

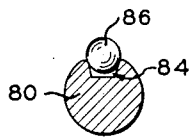


FIG. 7

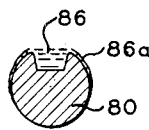


FIG. 7a

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APPARATUS AND METHOD OF COATING BY
VAPOR DEPOSITION

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Application June 30, 1950, Serial No. 171,432

10 Claims. (Cl. 117—107)

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This invention relates to coating and more particularly to vacuum deposition processes and apparatus which are particularly useful in coating aluminum on flexible and other substrate materials. This application is a continuation-in-part of the copending application of Clough et al. Serial No. 136,327, filed December 31, 1949, and is a continuation-in-part of the copending application of Godley et al., Serial No. 158,494, filed April 27, 1950.

It is a principal object of the present invention to provide an improved coating process that is reliable, cheap, and capable of high speed coating operations.

Another object of the present invention is to provide a process which is capable of long periods of operation for coating long rolls of substrate material without discontinuing the coating process.

Still another object of the invention is to provide a process of the above type wherein control of the coating operation may be readily achieved so as to provide uniformity of operation of the coating process over long periods of time.

Still another object of the invention is to provide an improved coating apparatus which is simple, reliable, and capable of operating for long periods of time to coat large areas of flexible substrate material.

Still another object of the invention is to provide such an apparatus which utilizes simple resistance heating of the metal to be evaporated, and which can be put into operation in an extremely short period of time.

Still another object of the invention is to provide an improved, cheap source for generating aluminum vapors which can be used in batch vacuum coating processes or in continuous coating 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 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 and the apparatus possessing the construction, combination of elements and arrangement of parts which are exemplified in the following detailed disclosure, and 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 embodiment of the invention;

Fig. 1A is a fragmentary, enlarged view of a portion of Fig. 1;

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Fig. 2 is a diagrammatic, schematic, partially sectional view taken along the line 2—2 of Fig. 1;

Fig. 3 is a diagrammatic, fragmentary, schematic, partially sectional view of another embodiment of the invention;

Fig. 4 is a diagrammatic, fragmentary, schematic, partially sectional view of another embodiment of the invention;

Fig. 5 is a diagrammatic, fragmentary, schematic, partially sectional view of still another embodiment of the invention;

Fig. 6 is a diagrammatic, fragmentary, schematic, partially sectional view taken along line 6—6 of Fig. 5;

Fig. 7 is a diagrammatic, fragmentary, schematic, partially sectional view taken along line 7—7 of Fig. 5; and

Fig. 7A is a diagrammatic, fragmentary, schematic view similar to Fig. 7 but showing a different condition of use thereof.

In one preferred embodiment of the invention there is provided a vacuum chamber in which the substrate to be coated may be moved past a source of aluminum vapors. The present invention is directed particularly to improvements in such aluminum-vapor sources. In one preferred aluminum-vapor source there is provided an elongated rod which is positioned transversely of the path of the substrate during the coating. This rod is preferably one which has at least a surface stratum which is wettable by molten aluminum, the rod preferably being formed of carbon and having a carbide surface stratum which is wettable by molten aluminum. Of the carbides, the carbides of the group IVa and group Va metals are preferred.

For holding the aluminum in contact with the rod, there is preferably provided a groove along the top of the rod, the apparatus being arranged so as to maintain this groove substantially completely filled with aluminum during the coating operation.

In the utilization of the apparatus described above, the vacuum chamber, after insertion of the substrate and aluminum supply, is evacuated to a low pressure on the order of a micron and then the rod is heated to a high temperature on the order of 1300° to 1500° C. by passing an electric current therethrough. Aluminum is then fed to the rod (if the rod was not initially filled with aluminum) so that aluminum may be evaporated from the rod. The aluminum carried by the groove in the rod, in a preferred embodiment of the invention, wets the whole outer surface of the rod and thus completely surrounds the rod so that aluminum is evaporated from all surfaces of the rod, thereby giving a line vapor source having a high vapor concentration.

In one preferred embodiment of the invention aluminum is fed to the rod in solid form, this aluminum preferably being provided as alumi-

num wire. For this embodiment of the invention one end of the rod is preferably cooled and the aluminum wire is fed into the groove at this cool end of the rod, this cool end of the rod being preferably at a temperature not much above the melting point of aluminum so as not to unduly complicate the wire-feeding mechanism. The aluminum wire is fed along the groove until it reaches a point where it is melted, due to the higher temperature of the rod at this particular point. In another embodiment of the invention, the aluminum is fed to the rod in a molten condition. In this latter form of the invention reservoir means are provided for confining a supply of molten aluminum adjacent one end of the rod, the molten aluminum being confined in the reservoir at a temperature not much above the melting point of aluminum, and being fed from the reservoir to the groove in the rod.

In the various embodiments of the invention, the feed of aluminum to the rod is preferably controlled as a function of the current flowing through the rod and the aluminum carried thereby. Since the aluminum has a lower resistivity than the carbon which is preferably utilized in the rod, the total resistance of the rod and the aluminum carried thereby will decrease as the amount of aluminum increases. This fluctuation in resistance may be utilized to control the feed of the molten aluminum through the groove in the rod, this feed being so adjusted that the resistance remains substantially constant, whereby the amount of aluminum carried by the rod at all times remains substantially constant.

In the various embodiments described above, the distribution of the aluminum along the groove in the rod is primarily achieved by the wetting action of the aluminum over the surface of the rod, however it also may be aided by gravity. In this case the rod may run downwardly from the aluminum supply (either solid or liquid) so that a flowing stream of aluminum is maintained in the groove at all times.

Referring now to Figs. 1, 1A, and 2, wherein like numbers refer to like elements in these and the other figures, there is shown a modification of one preferred embodiment of the invention wherein a grooved rod is employed as a source of the aluminum vapors, and aluminum in wire form is fed to a cool end of the grooved rod. In these figures, 10 represents a vacuum-tight housing defining therewithin a vacuum coating chamber 12 which is arranged to be evacuated by a vacuum pumping system schematically indicated at 14. Within this chamber the substrate 16 to be coated is guided from a supply 17 thereof past a plurality of water-cooled guiding rolls 18 to a take-up spool 19. During the process of the passage from supply 17 to take-up spool 19, the substrate 16 passes in a series of convolutions near a source 20 of aluminum vapors. The guiding rolls 18 are preferably driven and are so arranged that they do not "see" the vapor source 20. Thus the guiding rolls are not coated by the vapors from the source and are not exposed to direct heat radiation from the source. This protection of the rolls is particularly true of the row of rolls farthest from the source. This arrangement of rolls permits efficient cooling during and between all coating steps and provides a minimum of outgassing of heat-sensitive substrates. The source 20 preferably comprises a carbon rod 22 having a groove 24 in the upper surface thereof, this groove being preferably maintained full of molten aluminum 26. One end of the carbon

rod 22 is preferably supported by a first rod holder 28 while the other end thereof is supported by a second rod holder 30. These rod holders preferably comprise an inner collar element 32 preferably formed of segmental pieces of carbon supported inside an outer copper clamp 34. The rod holders are preferably arranged so that there is a poor electrical contact with the carbon rod and the various elements of the holders so as to generate some heat in the holders. In the preferred embodiment shown, these holders are cooled by cooling coils 36 which are in contact with the lower part of outer clamps 34, these cooling coils conveniently serving as one of the means to which electric current leads 38 are attached. Leads 38 are connected to a suitable source 40 of electrical energy, this source 40 being indicated as a transformer.

The aluminum 26 is preferably supplied from a wire coil 42 thereof, this wire coil being schematically indicated as being mounted upon a spindle 44 driven by a motor 46. This motor is controlled by a control means 48 which may, for example, be a rheostat. This control means 48 is in turn preferably controlled by a current-measuring device 50 which is arranged to measure the amount of current flowing through the leads 38, thus measuring the amount of current flowing through the rod 22 and the aluminum carried thereby.

In one preferred form of the invention there is provided a pair of radiation shields 51 which prevent any radiation from reaching the substrate which does not emanate from the molten aluminum surface. This arrangement gives a minimum of outgassing with heat-sensitive substrates. There may also be provided a trap 52 adjacent the second rod holder 30 for receiving any excess molten aluminum flowing from the rod adjacent the second rod holder 30.

In the operation of the device shown in Figs. 1, 1A, and 2, the roll 17 of the substrate 16 is positioned within the vacuum chamber 12 and the substrate is guided around the various rolls 18 and connected to the take-up spool 19. A spool of aluminum wire 42 is positioned on the spindle 44 and one end of the wire is guided into groove 24 adjacent that end of the rod 22 which is supported by the rod holder 28. Cooling water (at about 40° F. or lower) is then circulated through rolls 18 by suitable piping (not shown) so as to chill rolls 18. The vacuum chamber 12 is then evacuated to a low pressure, on the order of one micron, by means of vacuum pumping means 14. When the requisite low pressure is achieved the substrate is advanced, preferably by driving the take-up spool 19 and the various guiding rolls 18. Current supply 40 is then energized so that a current flows through the rod 22. Since the resistance of the rod 22 is relatively high, the current-measuring device 50 will indicate a need for aluminum. This indication is transmitted to the controlling means 48, thus energizing the motor 46 and causing aluminum wire to be fed from the spool 42 along the slot 24. In a preferred method of practicing the invention that end of the rod to which the aluminum wire is fed is maintained at a temperature somewhat above the melting point of aluminum (i. e., about 700°-800° C.). However, this temperature is not sufficiently high to cause immediate melting of the aluminum wire due to the high heat conductivity thereof. This temperature is readily controlled by the amount of heat generated in the rod holder 28, due to its internal resistance, and the

amount of cooling achieved by cooling coil 36 associated therewith. As the wire is advanced along groove 24 it finally reaches a point, preferably at about the left side of the holder 28, where the wire melts and the aluminum flows along the groove 24. The aluminum moves along the groove 24 by the wetting action of the aluminum on the wettable surface of the rod. If desired the aluminum may also be moved by gravity, the rod, in this case, being preferably tilted downwardly from the aluminum supply end to the other end thereof. As the aluminum wets the rod 22 a portion of the aluminum climbs out of the groove 24 and wets the circumference of rod 24 as indicated at 28a in Fig. 1A. After enough aluminum wire has been fed to the groove so that the groove is substantially completely filled with aluminum, the current flowing through the rod and the aluminum carried thereby will increase to a point where the current-measuring device 50 indicates that no further feed of aluminum is necessary in which case the controlling means 43 will prevent further feed of aluminum by stopping the motor 46. It is equally apparent that instead of completely stopping the feeding of aluminum wire, the feed thereof may be slowed down to a rate which is equal to, or less than, the amount of aluminum which is leaving the rod, either by evaporation or by running out of the other end of the rod.

In a preferred embodiment of the invention described above, the rod 22 preferably comprises carbon, several preferred grades of carbon rods being those manufactured by Becker Bros. under the designation "B-4," by National Carbon under the designation "G-A," and by Stackpole under the designation "CIH". Preferred forms of these carbon rods have a diameter of about $\frac{1}{4}$ " and a groove 24 of approximately $\frac{1}{8}$ " wide by $\frac{1}{2}$ " deep. A preferred method of pretreating the rods so as to form a surface stratum which is readily wet by molten aluminum comprises the steps of preparing a slurry of zirconia (ZrO_2), coating the rod with this zirconia slurry, drying the thus coated rod for about one hour at $110^\circ C.$, and then baking the coated rod at less than one micron of pressure and at a temperature of about $1450^\circ C.$ for a period of about one-half hour. After baking, the loose scale on the surface of the rod is then removed, most of the zirconia having formed a surface stratum of zirconium carbide on the rod. With a rod of the above type, which is about 4' long between the supports 28 and 30, there is obtained an aluminum evaporation rate greater than about 1 gram per minute when the rod is operated at a temperature of approximately $1400^\circ C.$ At such a temperature and rate of evaporation of aluminum, the substrate is preferably moved at a speed of about 100-150 linear feet per minute. The above rod, when carrying aluminum, has a voltage drop of about 2.5 volts per linear inch between the rod supports 28 and 30. With this voltage drop the current flowing through the aluminum-carrying rod is about 180 amperes, while the current flowing through the rod without aluminum is approximately 40 amperes. This difference between the current existing when the rod is filled with aluminum and the current existing when the rod is without aluminum gives, as mentioned above, an excellent means for controlling the feed of aluminum to the rod. The rod can be brought to its operating temperature very rapidly, the time necessary being only 10-15 seconds when the applied voltage is 2.5 volts per linear inch. When the ap-

plied voltage is higher, the rod may be brought to its operating temperature in less than a second. However, in this case it is desirable to reduce the voltage to about 2.5 volts per linear inch when the operating temperature is obtained.

Referring now to Fig. 3 there is shown still another embodiment of the invention wherein a plurality of rods 22, 22a, 22b, and 22c are provided along the path of travel of the substrate from the supply roll 17 to the take-up spool 19. In this embodiment of the invention the rollers 13 are preferably so arranged that there are two rows of the rollers 13, the axes of the lower row of rollers 13 being substantially parallel to the axes of the carbon rods 22, 22a, 22b and 22c. This embodiment of the invention has the advantage that a number of reserve rods may be kept in readiness for coating in the case that one or more of the other rods should break due to stresses arising during the operation of the rod at the elevated temperature employed. For example, the rod 22 may be the only rod which, during normal operation, is actually vaporizing aluminum. In this case the rods 22a, 22b and 22c are held in readiness in case the rod 22a should break. Since the present invention allows almost instantaneous heating of the rod to its operating temperature, if the rod 22 should break the rod 22a may be heated to a desired temperature of $1400^\circ C.$, or thereabouts, almost instantaneously so as not to interrupt the coating operation. The arrangement of Fig. 3 also has an additional advantage where it is desired to coat a very wide substrate. In this case it may be undesirable to have a single rod long enough to coat the whole width of the substrate. However, the Fig. 3 embodiment permits the use of a plurality of short rods, each short rod coating a portion of the transverse area of the substrate. Thus, for example, the rod 22 may coat a left-hand edge portion of the substrate, rod 22a may coat the center of the substrate, and rod 22b may coat the right-hand edge of the substrate. Obviously, various other modifications of the Fig. 3 form of the invention may be practiced depending upon the desired coating results to be obtained.

Referring now to Fig. 4 there is shown still another embodiment of the invention wherein the aluminum is supplied in molten condition to one end of the rod 22. In this embodiment of the invention, there is provided a reservoir 60 preferably comprising a carbon tube which is open at its bottom end, this bottom end being substantially completely filled by a solid plug 26 of aluminum. The upper end of the reservoir 60 is provided with a hole 62 through which aluminum can flow into groove 24. Adjacent the upper end of reservoir 60 there is also provided an induction heating coil 72 which is arranged to maintain the upper end of the plug 26 in molten condition by induction currents generated therein. This aluminum plug 26 is, in one form of the invention, carried by a screw-threaded member 66 which is fed by means of a nut 68 in an upwardly direction whenever a driving motor 70 is rotated. In a preferred embodiment of this form of the invention, the motor 70 is controlled by the current-measuring device 50 which operates upon the control means 43 previously discussed in connection with Figs. 1 and 2. With this embodiment of the invention, whenever the aluminum supply in the groove 24 falls to a point so as to reduce the current flowing through the rod 22 and the aluminum carried thereby, the current-measuring device 50 actuates the control

means 48 so as to energize the motor 70, thus causing the aluminum plug 26 to travel upwardly into the field of induction coil 72 thereby melting more of the upper end of this plug.

While the invention has been described particularly in its preferred use for the continuous coating of a flexible substrate, it is equally applicable to batch type of coating operations wherein a number of metallic or plastic objects to be coated are mounted within a vacuum coating chamber and are coated by creating an atmosphere of aluminum vapors within the vacuum chamber. In this embodiment of the invention, shown in Figs. 5, 6, 7, and 7A, there are provided a plurality of carbon rods 80, these rods preferably comprising zirconium or other carbide surface strata prepared in a manner similar to that described previously. Each of these rods is supported by rod holders 82, it being preferred that short lengths of rod of about 4-6 inches be employed. These are connected in series to give any desired length requisite for the dimensions of the coating chamber. Each of these rods is preferably provided with a groove 84 at the top thereof, these grooves being of such size as to support a plurality of aluminum pellets 86. As shown more particularly in Fig. 6, each rod 80 is supported at its ends by rod holders 82, these rod holders each comprising a pair of segmental collars 90, a yoke member 92, and a spring clamp 94 for securing the collars 90 around the rod. In the use of the device of the type shown in Figs. 5, 6, 7, and 7A, the objects to be coated are placed in the vacuum coating chamber along with the rods 80 carrying the aluminum to be evaporated. The chamber is then evacuated to the requisite low pressure and current is passed through the various rods 80 by applying a suitable voltage, on the order of 2.5 volts per linear inch, to the rods. This current, as mentioned previously, heats the rod to a high temperature on the order of 1400° C., thereby melting the aluminum pellets 86 and filling the grooves 84 with molten aluminum. In a preferred use of this embodiment of the invention, a portion of this molten aluminum, due to the wetting action thereof on the zirconium carbide surface, spreads out and covers substantially the whole outer surface of the rod 80 as indicated at 86a in Fig. 7A. However, where directional control of the vapors is desired the groove 84 may be only partially filled so that evaporation of all the aluminum is achieved before any substantial wetting of the outer surface of the rod occurs.

The arrangement of elements shown in Figs. 6 through 7A thus provides a very cheap source of aluminum vapors which may be used almost indefinitely and which can be very readily loaded and reloaded with aluminum pellets. If desired, the rods 80 may be installed in the coating device with the aluminum in solid form completely or partially filling groove 84, this embodiment of the invention eliminating the necessity of loading the individual grooves with pellets prior to the coating operation. However, since the rods will last for a great number of coating operations, they may be readily refilled as soon as all of the aluminum has been evaporated therefrom.

While one preferred type of rod 22 has been described in connection with the various embodiments of the invention, other forms thereof may be employed. For example, the rod 22 may comprise titanium carbide such as that sold by Kentanmetal, Inc. under the designation "Kentanium" K138. This is an extruded cemented titanium

carbide sintered with cobalt. Additionally, other materials of the type described in the above-mentioned Godley et al. application, Serial No. 158,-494, may be used in forming the rods 22.

In one preferred method of forming a wettable carbide surface on the carbon rod 22, a molten bath of aluminum and a group IVa or group Va metal, for example zirconium, is maintained in a vacuum. While in this vacuum the rod, whose surface is to be formed into a carbide, is dipped into this molten bath, thereby converting the surface of the rod to the desired zirconium carbide. By the group IVa and group Va metals are meant titanium, zirconium, hafnium, vanadium, columbium and tantalum.

Equally other methods of feeding aluminum to the rods may be employed as illustrated in the above Godley et al. application. Similarly, resistance measurements may be made of the coated web as it travels through the coating chamber, these resistance measurements being used to control the rate of speed of the web or the temperature of the rods and the aluminum thereon.

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. Apparatus for coating a substrate with aluminum by vacuum evaporating said aluminum and condensing said aluminum on said substrate, said apparatus comprising a vacuum chamber, means providing a source of aluminum in said vacuum chamber, means for evacuating said chamber, an elongated rod having a groove along the top thereof positioned within said chamber, said rod having a surface wettable by molten aluminum, said surface comprising a compound selected from the group consisting of the carbides and nitrides of titanium, zirconium, hafnium, vanadium, columbium and tantalum, means for feeding aluminum from said source thereof to said rod adjacent one end thereof at a rate sufficient to keep said groove substantially completely filled with molten aluminum, means for passing an electric current through said rod and the aluminum carried thereby to heat said aluminum to a temperature above about 1300° C., means for maintaining that end of the rod to which said aluminum is fed at a temperature not much in excess of the melting point of aluminum, means for moving said substrate past said rod to give a substantially uniform coat of said aluminum on said substrate, means for measuring said electric current passing through said rod and said aluminum carried thereby, and means responsive to said current-measuring means for controlling the operation of said aluminum-feeding means so as to maintain a substantially uniform amount of aluminum on said rod.

2. Apparatus for coating a heat-sensitive substrate with aluminum by vacuum-evaporating said aluminum and condensing said aluminum on said substrate, said apparatus comprising a vacuum chamber, means providing a source of aluminum in said vacuum chamber, means for evacuating said chamber, an elongated element having a groove along the top thereof positioned within said chamber, said element having a surface wettable by molten aluminum, said surface comprising a compound selected from the group

consisting of the carbides and nitrides of titanium, zirconium, hafnium, vanadium, columbium and tantalum, means for feeding aluminum from said source thereof to said element at a rate sufficient to keep said groove substantially completely filled with molten aluminum, said wettable surface on said element assuring coverage by molten aluminum of a substantial surface portion of said element in addition to said groove, means for heating said aluminum to a high temperature to vaporize said aluminum, means for moving said substrate past said element to coat said aluminum on said substrate, and means for guiding said substrate during its movement past said element so that said substrate is exposed to heat radiation only from those surfaces of said element which are covered by molten aluminum.

3. The apparatus of claim 2 wherein said heating means comprises means for passing electrical current through said element and the aluminum carried thereby, said apparatus including means for measuring said electric current, and means responsive to said current-measuring means for controlling the operation of said aluminum-feeding means so as to maintain a substantially uniform amount of aluminum on said element.

4. The apparatus of claim 2 wherein said substrate-moving means comprises a plurality of rolls for guiding said substrate in a generally curved path around said elongated element as said substrate moves through said vacuum chamber, the axes of said rolls being substantially parallel to the long dimension of said element.

5. The apparatus of claim 2 wherein said substrate-moving means comprises a plurality of rolls for guiding said substrate through said vacuum chamber and a plurality of said elongated elements are provided for vaporizing aluminum, the long dimensions of said elements and said rolls being substantially parallel.

6. In a process for coating a moving substrate with aluminum by vacuum-evaporating said aluminum and condensing said aluminum on said moving substrate, the improvement which comprises the steps of feeding aluminum to a groove in the upper surface of a generally cylindrical elongated heated surface, said feeding being at a rate sufficient to maintain molten aluminum on said surface at substantially all times during coating, providing on said surface at least a stratum comprising a compound selected from the group consisting of the carbides and nitrides of titanium, zirconium, hafnium, vanadium, columbium and tantalum, said compound being wettable by, and substantially inert to, molten aluminum at temperatures on the order of 1300° C. to cause said aluminum to spread out in a thin extended layer of substantially greater size than the groove to which the aluminum is fed so that substantially all portions of said surface in position to radiate substantial quantities of heat to the substrate are covered by molten evaporating aluminum, heating said surface and the aluminum thereon to a temperature sufficiently high to evaporate the aluminum, and moving said substrate past said surface in a generally curved path to expose the substrate to aluminum vapors generated on the sides, as well as the top, of said elongated cylindrical surface to deposit a coat of aluminum on the substrate.

7. In a process for coating a moving substrate with aluminum by vacuum-evaporating said aluminum and condensing said aluminum on said

moving substrate, the improvement which ported on an elongated grooved rod having a surface wettable by molten aluminum and substantially inert to molten aluminum at temperatures on the order of 1300° C., the improvement which comprises feeding aluminum to the groove in said rod adjacent one end thereof at a rate sufficient to keep said groove substantially completely filled with molten aluminum so that said aluminum wets a substantial arcuate portion of said rod surface in addition to said groove, heating a portion of said rod and the aluminum in said groove to a temperature above about 1300° C. and below about 1500° C. by passing an electric current through said rod and said aluminum, maintaining that end of said rod to which said aluminum is fed at a temperature not much in excess of the melting point of aluminum, and moving said substrate past said rod to give a substantially uniform coat of said aluminum on said substrate, said wetting of said rod surface being sufficient to cover substantially all surfaces of said rod which can radiate heat to said substrate.

8. In a process for coating a moving substrate with aluminum by vacuum-evaporating said aluminum and condensing said aluminum on said moving substrate, and the improvement which comprises the steps of feeding aluminum to and supporting molten aluminum on, an elongated heated surface, said feeding being to a limited area of said surface and being at a rate sufficient to maintain molten aluminum on said surface at substantially all times during coating, providing on said surface at least a stratum comprising a compound selected from the group consisting of the carbides and nitrides of titanium, zirconium, hafnium, vanadium, columbium and tantalum, said compound being wettable by, and substantially inert to, molten aluminum at temperatures on the order of 1300° C. to cause said aluminum to spread out in a thin extended layer of substantially greater size than the limited area to which the aluminum is fed so that substantially all portions of said surface in position to radiate substantial quantities of heat to the substrate are covered by molten evaporating aluminum, heating said surface and the aluminum thereon to a temperature sufficiently high to evaporate the aluminum, and moving said substrate above said surface to deposit a coat of aluminum on said substrate.

9. The process of claim 8 wherein solid aluminum is fed towards said limited area and is melted as it approaches said limited area.

10. The process of claim 8 wherein molten aluminum is fed to said limited area.

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