April 21, 1953 E. E. CHADSEY, JR 2,635,579

COATING BY EVAPORATING METAL UNDER VACUUM

Filed Dec. 1, 1949

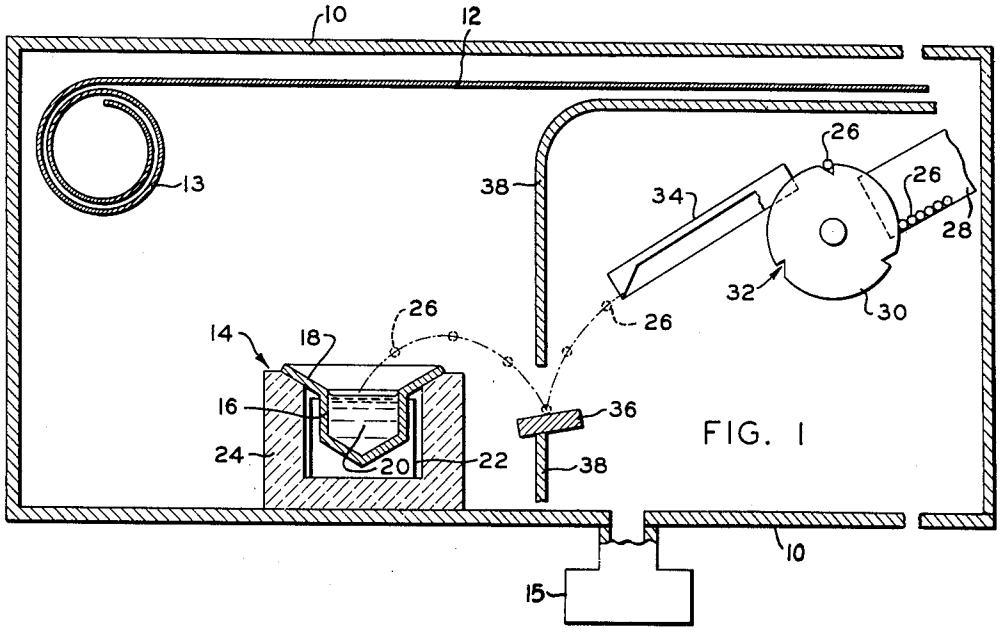


FIG. 1

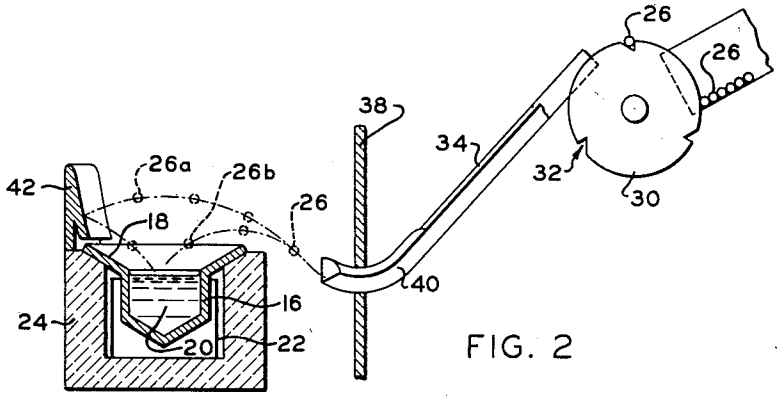


FIG. 2

INVENTOR.

BY EARL E. CHADSEY, JR.

Oliver W. Hayes

ATTORNEY

Patented Apr. 21, 1953

2,635,579

UNITED STATES PATENT OFFICE

2,635,579

COATING BY EVAPORATING METAL UNDER VACUUM

Earl E. Chadsey, Jr., Newton, Mass., assignor to National Research Corporation, Middlesex County, Mass., a corporation of Massachusetts

Application December 1, 1949, Serial No. 130,453

4 Claims. (Cl. 118—49)

1

This invention relates to coating and more particularly to improved apparatus and methods for feeding a metal to a metal-evaporating crucible in a vacuum coating system.

A principal object of the present invention is to provide an improved metal-feeding apparatus for replenishing metal to be melted and vaporized in a crucible positioned within a vacuum coating chamber.

Another object of the invention is to provide an improved apparatus, of the type described above, which is capable of feeding metal accurately over long periods of time without interfering with efficient and uniform coating operations, the metal-feeding apparatus being arranged so that there is a minimum amount of condensation of metal vapors thereon.

Still another object of the invention is to provide improved methods for feeding pellets, of the metal to be coated, to a metal-evaporating means.

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 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 an exaggerated, diagrammatic, partially sectional view of one preferred embodiment of the invention; and

Fig. 2 is a fragmentary view similar to Fig. 1 showing a modification of a portion of the apparatus of Fig. 1.

In general the present invention is directed to improved apparatus and methods for feeding metal from a supply thereof to a metal-evaporating means in a vacuum coating device. Since the time necessary to evacuate the coating chamber to the requisite low pressure is quite considerable, it is extremely advantageous to provide continuous operation of the metal-evaporating means. This can only be accomplished by providing a means for replenishing the metal as it is evaporated. For maximum efficiency and uniformity of coating, the metal-feeding means should not be so positioned as to interfere with

2

the vapor stream passing between the metal-evaporating means and the substrate to be coated. In the present invention the above advantages are achieved by the novel arrangement of the various elements comprising the metal-feeding apparatus. In one preferred form of the invention, the apparatus includes a vacuum-tight chamber and a means for evaporating the metal to be coated on the substrate. This metal-evaporating means preferably comprises an open-mouthed crucible. The substrate to be coated is arranged to be fed above the crucible so that the metal vapors rising therefrom will condense on the substrate. The apparatus includes a means for holding a supply of pellets of the coating metal, and means for feeding individual pellets from the supply. Associated with the feeding means is a means for guiding a fed pellet along a path spaced from the crucible and extending below the mouth of the crucible. Positioned at the bottom of the path of the pellet is a deflecting means which is arranged to deflect the pellet and to impart an upward and lateral motion to the pellet so as to cause the pellet to travel, under the influence of kinetic energy acquired during its downward movement, in an arc terminating in the open mouth of the crucible.

Referring now to Fig. 1 there is shown one preferred form of the invention wherein the deflecting means comprises a bounce plate upon which the pellet falls and then rebounds into the crucible. In the apparatus of Fig. 1 there is provided a vacuum-tight chamber 10 arranged to be evacuated by a suitable vacuum pumping system 15. The material to be coated, such as a flexible, nonmetallic substrate, is indicated at 12 as being arranged to be fed from a supply (not shown) to a windup coil 13 therefor. The metal-evaporating means, generally indicated at 14, is shown in a preferred form as comprising a metal-evaporating crucible 16 including a lip 18 defining the mouth of the crucible. This crucible holds a predetermined quantity of the coating metal 20, this metal 20 being heated to evaporation temperature by a suitable source of heat, such as a radiant heating element 22. Crucible 16 is preferably supported within an outer refractory crucible 24 which also serves the additional function of preventing heat loss from the radiant heating element 22. The particular type of crucible and heating element shown in Fig. 1 is described and claimed in the copending application of Noble E. Hamilton, Serial No. 117,444, filed September 23, 1949, now abandoned.

The metal replenishing system, with which the

present invention is particularly concerned, is shown diagrammatically as comprising a number of pellets 26 contained in a suitable supply 28 therefor. For removing the individual pellets from the supply 28, there is provided a feeding means, such as a wheel 30, having a plurality of pellet-engaging notches 32 in the periphery thereof. This wheel may be suitably rotated by a number of mechanisms employed for introducing mechanical motion into a vacuum system. Examples of such mechanisms are shown in Industrial and Engineering Chemistry, vol. 39, page 1065 (1947), and U. S. Patents 2,482,329, 2,410,720 (Dimmick) and 2,403,199 (Swope). As the wheel 30 rotates in a counterclockwise direction, each notch 32 picks up an individual pellet 26 and deposits this pellet 26 in a trough 34. Positioned below and spaced from the end of trough 34 is a bounce plate 36. This bounce plate 36 is preferably positioned below the level of the lip 18 of the open-mouthed crucible 16 so as to be removed from the vapor stream emanating from the molten metal 20 in the crucible. For preventing travel of any portion of the vapor stream to the metal-feeding mechanism, there is provided a shield 38. As can be seen, the end of the shield 38, adjacent the top of the bounce plate 36, extends below the direct-line path of vapor emanating from the surface of the molten pool 20. The majority of the vapor emanating from the surface of the molten metal travels nearly normally from this surface, and the greatest concentration of these vapors is therefore within a cone having outer limits about 45° with respect to the normal. Thus, a very small percentage of the metal vapor diffuses down below the lip of the crucible and below the bottom end of shield 38.

The bounce plate 36 is sufficiently low and so positioned that the kinetic energy acquired by an individual pellet 26, during its rolling down the trough 34 and falling from the end of the trough to the bounce plate, is sufficient to cause the pellet 26 to rebound along the curved dotted-line path into the mouth of the crucible 16. The angle at which the pellet strikes the bounce plate, the kinetic energy of the pellet, and the rebound characteristics of the bounce plate are so adjusted that the curved path of the pellet terminates in the crucible mouth.

In a preferred form of the invention, where the metal to be evaporated is aluminum, the metal-evaporating crucible 16 preferably comprises a carbon-graphite crucible lined with zirconium carbide of the type described in the copending application of Chadsey et al., Serial No. 117,124, filed September 22, 1949. The other elements, such as the heater element 22 and the outer crucible 24, are also preferably formed of materials specified in the previously mentioned Hamilton application. The bounce plate 36 preferably comprises a relatively soft, resilient material which will give a relatively high percentage of bounce to the aluminum pellet 26. The preferred material for this purpose comprises the carbon-graphite combination sold under the trade name of "Graphitar," this material being soft enough so as not to flatten the aluminum pellet when the pellet strikes the "Graphitar" and having a sufficient resiliency to give a rebound of approximately 70% of the height from which the pellet has fallen. This allows the bounce plate to be spaced both a substantial distance from the mouth of the crucible and a substantial distance below the mouth of the crucible.

In the operation of the above-described device, a supply of pellets 26 may be initially provided in the metal-evaporating crucible 16. After the vacuum chamber 10 has been evacuated, the heater element 22 is energized to raise the temperature of the crucible 16 to the point where the pellets are melted to provide the molten pool 20. For maximum evaporation efficiency, the level of the molten pool is preferably maintained at about the level illustrated. As the metal is evaporated, due to the high temperature thereof and the low residual pressure in the chamber, the level of the metal in the crucible drops and an additional pellet is fed thereto. For accomplishing this result, the wheel 30 is rotated in a counterclockwise direction. As the notch 32 passes the supply 28, it picks up an individual pellet and drops this pellet into the trough 34. The pellet then rolls down the trough, rolls off the end of the trough, strikes the bounce plate 36, and rebounds into the open mouth of the crucible. The rotation of the wheel 30 may be accomplished manually by observing the level of molten metal in the crucible, or it may be operated automatically in accordance with a predetermined cycle.

The present invention has a number of advantages. It is accurate and mechanically simple. It provides a coating apparatus which is capable of long runs so as to give a maximum output of coated material from a particular coating apparatus. There is no condensation of the coating metal on the moving parts of the pellet-feeding mechanism. Additionally, the present invention has the extremely important advantage of providing no interference with the vapor stream emanating from the metal-evaporating crucible. This is of the utmost importance where uniform coatings of wide areas of a substrate are to be provided. It completely eliminates any "shadows" which might arise in the evaporated coating on the substrate.

In Fig. 2 there is shown another modification of the invention wherein the deflecting means comprises a portion of the apparatus which relatively gradually changes the direction of the motion of the pellet rather than causing the abrupt change of direction embodied in the bounce plate 36 of Fig. 1. In Fig. 2, where like numbers refer to like elements in the preceding figure, the pellet-deflecting means comprises a tube 40 which constitutes an extension of the trough 34. This tube 40 is preferably covered on that portion thereof which extends through the shield 38. Fig. 2 additionally shows a modification of the crucible which can be applied to the Fig. 1 form of the invention, and which comprises the addition of a barrier 42 adjacent one lip of the crucible. This barrier 42 has the function of deflecting back into the crucible any pellet which, due to a greater weight or a lower coefficient of friction or other irregularity, follows, during its course of flight, a path indicated at 26*a* rather than the normal path 26*b* for which the apparatus is preferably adjusted.

In those cases where there is a tendency of the coating metal to condense on the barrier element 42, this element may be heated to a temperature sufficient to prevent such condensation, or to a temperature such that any condensed metal will drip back onto lip 18. It can thus be seen that barrier 42, in effect, serves as an extension of lip 18 of the crucible.

In the operation of the Fig. 2 device, the individual pellets, rolling down the trough 34 and

through the curved pipe **40**, contain a sufficient kinetic energy so as to follow a trajectory which terminates within the crucible mouth. As can be seen from Fig. 2, the open end of the curved tube **40** is positioned below and spaced from the mouth of the crucible so as to be removed from the vapor stream emanating from the crucible. It thus has the advantages enumerated in the preceding discussion of Fig. 1.

The metal-evaporating crucible, shown in the drawings, can be considerably modified. For example, it may be of the type described in the previously mentioned copending application of Chadsey et al., or it may comprise other types of metal-evaporating crucibles shown in the prior art. Numerous examples of such crucibles are shown in the following U. S. Patents: 1,584,728, Case, May 18, 1926; 2,074,281, Sommer, March 16, 1937; 2,157,478, Burkhardt et al., May 9, 1939; 2,337,679, Osterberg, December 28, 1943; 2,374,331, Cooke, April 24, 1945; 2,378,476, Guellich, June 19, 1945; 2,382,432, McManus et al., August 14, 1945; 2,384,500, Stoll, September 11, 1945; 2,387,970, Alexander, October 30, 1945; 2,405,662, McManus et al., August 13, 1946; 2,423,729, Ruhle, July 8, 1947; 2,554,902, Godley, May 29, 1951; 2,562,182, Godley, July 31, 1951.

Additionally, it should be apparent that other feeding means than those specifically illustrated may be embodied in the invention without departing from the scope thereof. Additionally, a suitable modification of the structure for imparting kinetic energy to the individual pellets may be incorporated in a structure of the type shown. For example, the kinetic energy imparted to the pellet may be provided by a spring mechanism or other source of energy rather than, or in addition to, the force of gravity utilized in the illustrated embodiments.

In some cases it is desirable to vary the rate of feed of the pellets. In such cases the variations of the speed of rotation of wheel **30** may be quite substantial and the kinetic energy of the pellet **26** fed to the top of the trough **34** is apt to vary considerably, with a consequent variation of the speed with which the pellet leaves the lower end of trough **34**. This disadvantage may be readily overcome by modifying the apparatus of Fig. 1 so that the plane of rotation of wheel **30** is normal to the plane of the trough. With this modification each pellet starts to roll down the trough with virtually no initial velocity.

Since certain changes may be made in the above apparatus and process 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. The process of replenishing a supply of metal in an open-mouthed, metal-evaporating crucible positioned in a vacuum-tight coating chamber which comprises providing a supply of pellets of said metal, imparting a predetermined amount of kinetic energy to an individual pellet so as to cause said pellet to travel in an arc commencing at a point laterally spaced from and below said crucible mouth and terminating in the vicinity of the crucible mouth, and shielding the point of commencement of said arc from the metal vapor stream emanating from said crucible mouth.

2. Apparatus for coating a substrate with a metal by evaporating said metal in a vacuum and condensing said metal on the substrate, said apparatus comprising a vacuum-tight chamber, an open-mouthed crucible for melting and evaporating said metal, means for positioning said substrate above said open mouth of said crucible, means for holding a supply of pellets of said metal, means for feeding individual pellets from said supply and along a path spaced from said crucible and extending downwardly below the mouth of said crucible, and means for deflecting said pellet at the bottom of its path to impart an upward and lateral motion to said pellet to cause said pellet to travel, under influence of kinetic energy acquired during its downward movement, in an arc terminating in said open mouth of said crucible, said deflecting means being shielded from the metal vapor stream emanating from said crucible mouth.

3. The apparatus of claim 2 wherein said open mouth of said crucible includes an outwardly and upwardly extending lip means.

4. The apparatus of claim 3 wherein a portion of said lip means is enlarged to assure termination of said path within said mouth.

EARL E. CHADSEY, JR.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
1,570,949	Cunningham et al.	Jan. 26, 1926
1,707,294	Woodson	Apr. 2, 1929
2,074,281	Sommer	Mar. 16, 1937
2,151,737	Bryan	Mar. 28, 1939
2,153,786	Alexander et al.	Apr. 11, 1939
2,387,970	Alexander	Oct. 30, 1945
2,426,377	Smith	Aug. 26, 1947
2,440,135	Alexander	Apr. 20, 1948