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2,909,149

APPARATUS FOR EVAPORATING METAL

Filed Nov. 15, 1957

2 Sheets-Sheet 1

FIG. 1.

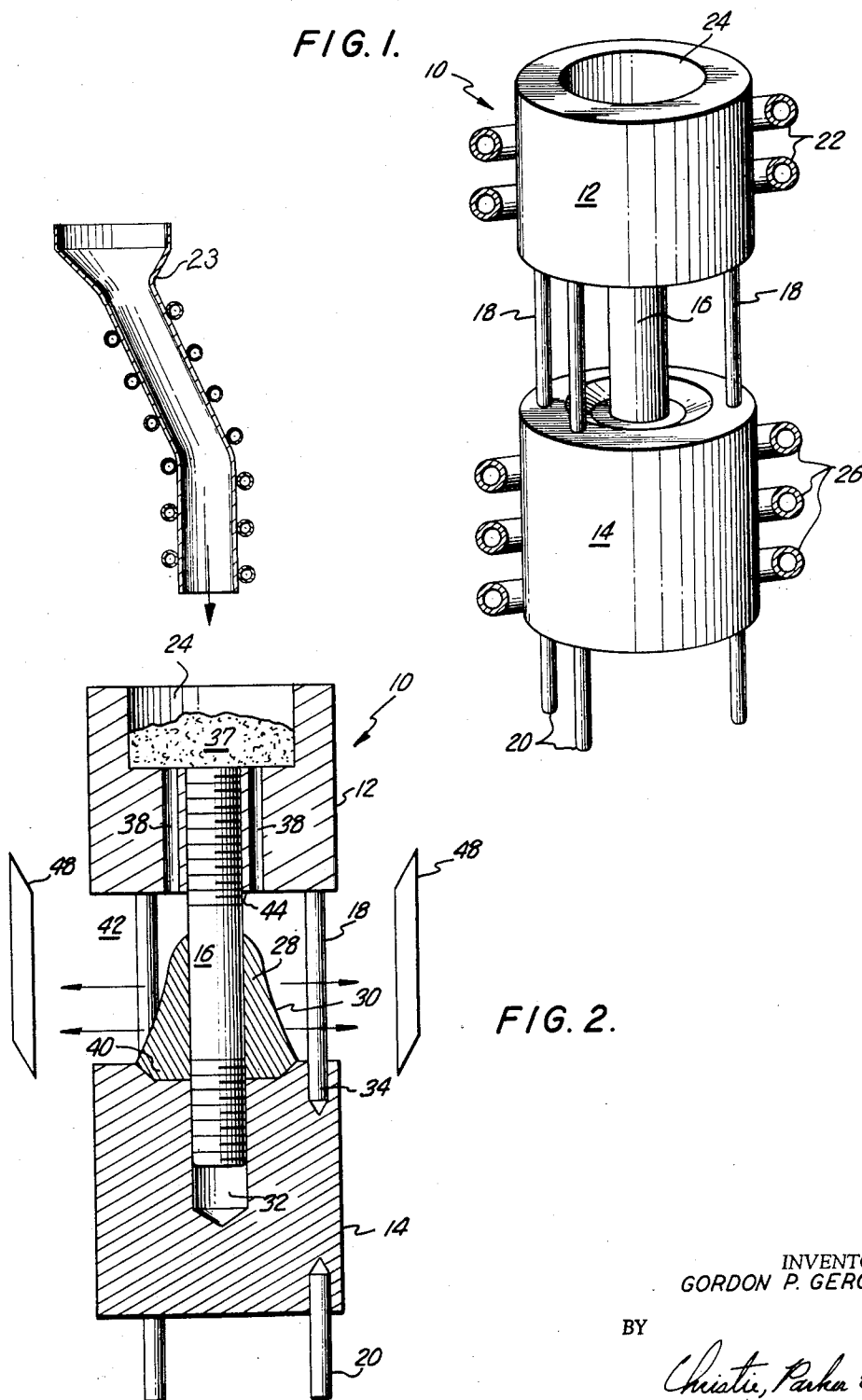
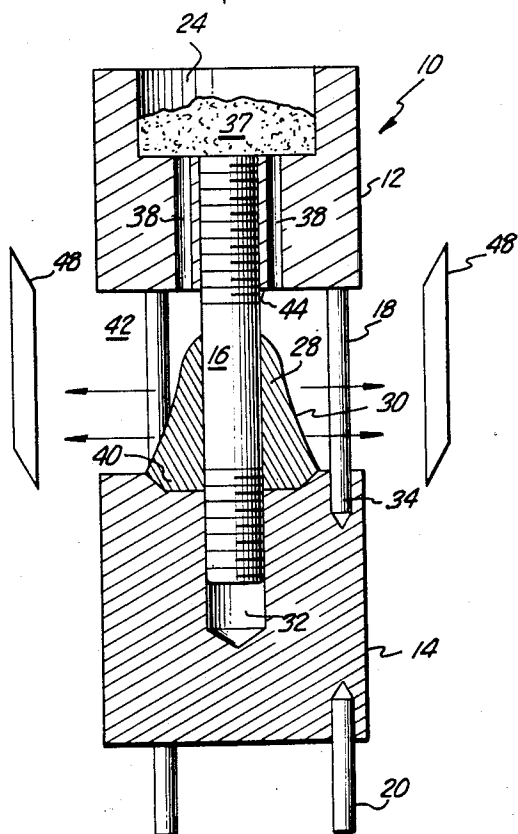


FIG. 2.



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FIG. 3.

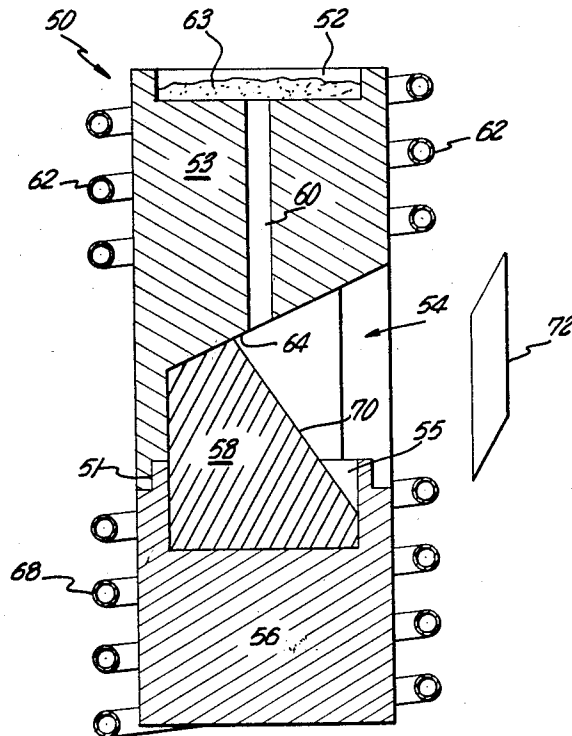
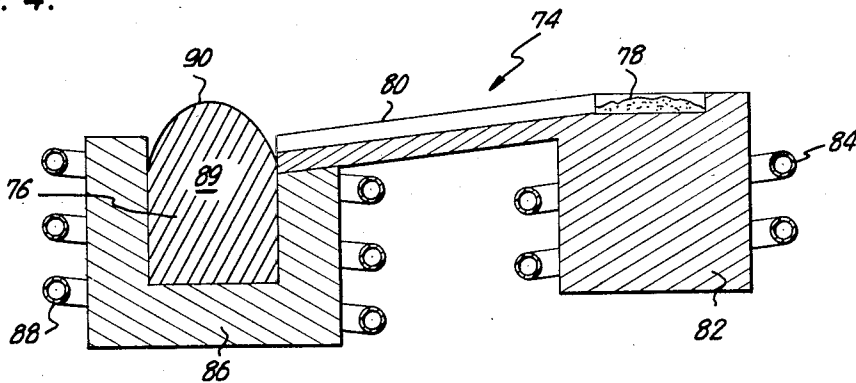


FIG. 4.



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3 Claims. (Cl. 118—49.1)

This invention relates to methods and apparatus for thermally evaporating coating materials in a vacuum to produce vapors for coating substrate.

The emission of vapor from a coating source is generally in an upward direction from the evaporating coating material. In many instances, controlling the direction of the emission is desirable due to a preferred location of the substrate during the coating process. The present invention provides for directing the vapor emission laterally to coat substrate located laterally adjacent the source.

The preferred embodiment of the present invention continuously supplies molten coating material to the source where the material is inductively heated to evaporate it. The field of the inductive heater supports the lateral sides of the charge of molten coating material in the source to provide a liquid-vapor interface of coating material which is approximately vertical and directing the emission of vapors laterally from the source. The substrate to be coated is disposed laterally adjacent the source, preferably in a vertical plane, to provide coating surfaces at right angles to the direction of the vapor emission. The continuous supply of material to the coating source has been provided by melting the coating material in a melting chamber and continuously supplying the molten material to an evaporation chamber.

The molten coating material in the evaporation chamber supported by the field of the inductive heating coil preferably is stabilized by a wetted surface of a vertical column passing through the center of the material. The central column permits all the lateral surface to be exposed, however, if the emission of vapors in all lateral directions is unnecessary, the stabilizing surface may be adjacent the side of the material that need not be exposed.

This invention is explained with reference to the accompanying drawings, in which:

Fig. 1 shows a preferred embodiment of the invention;

Fig. 2 is a cross sectional view of the coating source shown in Fig. 1, and additional apparatus;

Fig. 3 is a cross sectional view of an alternate embodiment of the coating source for directing vapors in a predetermined lateral direction; and

Fig. 4 is a cross sectional view of another embodiment of the invention.

Referring to the drawings, there is shown in Fig. 1 a preferred coating source 10 including cylindrical carbon crucibles or heater elements 12 and 14 supported in vertically spaced relation by a column 16 and shafts 18. The lower crucible 14 is supported on legs 20 extending from the bottom of the crucible.

In the preferred embodiment, the upper crucible 12 is heated by an inductive heating coil 22 surrounding the crucible 12 and the melting chamber 24 formed therein. A suitable high frequency supply source, connected to the terminals of the inductive heating coil 22 supplies power to the coil for melting coating material placed in the melting chamber 24. A lower heating coil 26 surrounds the crucible 14 to heat the crucible and the coat-

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ing material supplied to the evaporation chamber from the melting chamber. The inductive heating coil 26 connected to the same source as coil 22 or another high frequency power source, heats the coating material in the evaporation chamber to thermally evaporate the coating material. The field of the coil 26 also acts to laterally compact and support the molten material about the central column 16 as shown in Fig. 2. Supply source frequencies from 5 to 50 kilocycles have been found adequate for producing a field laterally supporting the molten coating material in the evaporation chamber. The lateral support of molten material by the electromagnetic field of an inductive heating coil, sometimes referred to as the "pinch effect" is described in more detail in U.S. Patent No. 2,584,660, to G. H. Bancroft, issued February 5, 1952.

The cross-sectional view of the coating source shown in Fig. 2 illustrates the support effect of the field set up by the inductive coil 26. The molten coating material 28 is laterally supported at a steep angle about the column 16 providing approximately vertical liquid vapor interface 30 for lateral emission of coating material vapors.

The lower crucible 14 includes a central bore 32 which may be tapped to secure the lower portion of carbon column 16 to the crucible. Annular bores 34 about the top periphery of the crucible 14 seats the ends of carbon support shafts 18 which abut the lower opposing surface of the upper crucible 12. The shafts 18 provide additional support for the upper crucible 12 and are preferred because of the low tensile strength of carbon material used in the column 16.

The upper crucible 12 includes a melting chamber 24 opening upwardly for receiving the coating material 37 normally supplied to the chamber in its solid state through a water-cooled guide tube 23. A plurality of feeding channels 38 located at equal distances from the vertical axis extend vertically from the melting chamber 24 and have outlets opening over the recess 40 in the upper surface of the crucible 14 for feeding molten coating material from the melting chamber 24 to the evaporation chamber 42.

A central bore 44 extends vertically from the lower surface of crucible 12 along the crucible axis to seat the upper threaded portion of the column 16. The internal periphery of the bore 44 may be tapped to receive the upper threaded portion of the column 16 which is shown projecting into the bore.

Preferably, the coating sources including the crucibles, shafts, column, and legs are machined from relatively pure carbon, for example, a type commercially known as "Spear-580" carbon can be used. However, an even harder carbon would provide additional advantages as a heater element or crucible.

In operation, the coating material 37, preferably in the form of powder or chopped wire, is supplied through a water-cooled guide tube 23 to the melting chamber 24 for pre-melting. The temperature in this area is maintained relatively low to prevent appreciable evaporation of coating material, thus eliminating build-up of condensed coating material on the lower end of the water-cooled guide tube 23 while providing a degassing area for the coating material 37 prior to feeding it into the evaporation chamber 42. A build-up of condensed coating material on guide tube 23 could interfere with the feeding of solid material to the melting chamber 24. The pre-melting and degassing of the coating material in the chamber 24 reduces spattering and gases in the evaporation chamber 42.

The flat bottom surface of the melting chamber 24 provides adequate retention of the molten coating material, eliminating the need for a raised entrance to the feed channels 38. The material 37 melted in the melting

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chamber 24 passes through the feed channels and drops from the channel outlets into the evaporation chamber 42.

In practicing the invention, the material dropping down into the evaporation chamber has not caused splashing. However, the outlets of the feed channels may project adjacent to a wall such as provided by column 16 to permit the molten metal to drain into the evaporation chamber 42 while eliminating any possibility of splashing from the molten coating material 28 falling into the evaporation chamber.

Although the supply of molten coating material is considered to be continuously feeding into the evaporation chamber of the various embodiments, it should be noted that in normal operation, the molten material builds up in the feed channels and passes through the channels intermittently to the evaporation chamber. The resulting intermittent feeding is considered to be continuously supplying molten coating material to the evaporation chamber.

The molten material 28 collecting in the evaporation chamber 42 emits vapors of the coating material from the sloping liquid vapor interface 30. The substrate 48, positioned in a vertical plane and directly opposite the vapor source 42, is coated by the vapors emitted in a lateral direction from the coating material interface. A substantial portion of the vapors emitted from the sloping top of the molten coating material 28 are reflected from the bottom surface of the carbon crucible 12. As the vapor reaching the bottom surface of the crucible 12 condenses it is returned to the lower part of the chamber joining the mass of molten coating material 28 for re-evaporation.

A satisfactory embodiment of the preferred coating source 10 was constructed spacing the crucibles 12 and 14 by approximately one inch. A guide tube 23, having an internal diameter of $\frac{3}{8}$ inch, did not clog at the temperatures necessary for melting the coating material 37 in the chamber 24. While in operation, the best coating results on the substrate were obtained when the substrate was located in a vertical plane directly opposite the source, whereby the vapor would strike the surface of the substrate at right angles.

A directional coating source 50 is shown in Fig. 3 and includes an upper melting chamber 52 and a lower evaporation chamber 54. The coating source is preferably machined from bodies of pure carbon joined at an annular lap joint 51 to provide a melting chamber 52 opening at the top surface of the upper body portion 53 and a recess 55 in the top surface of the lower body portion 56 for supporting molten coating material 58 in the evaporation chamber 54. The melting chamber 52 is connected to the evaporation chamber 54 by at least one feed channel 60. An inductive heating coil 62 heats the upper portion of the source 50 to pre-melt the coating material 63. The molten material drains down the feed channel 60 to the vapor chamber 54 along a path including an inclined wall 64 located adjacent the outlet of the feed channel 60 to join the mass of molten coating material 58 in the recess 53 and evaporation chamber 54.

An inductive heating coil 68 is supplied from a high frequency source, preferably from 5 to 50 kilocycles, which is connected to the coil for heating the lower body portion 56 to evaporate the coating material 58. The field of the coil laterally compacts the molten coating material 58 to support the material and provide a sloping vertical liquid vapor interface 70 from which vapors of coating material are emanated to coat substrate 72 disposed opposite the coating material interface. The vapors emanating from the coating material 58 in other directions surrounded by wall of the evaporation chamber 54 are reflected or condensed on the carbon surfaces of the walls and returned to the mass of molten material for re-evaporation.

Fig. 4 shows an alternate embodiment of the invention in which an evaporation chamber 73 may be continuously

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supplied with coating material. The coating source 74 is preferably machined from pure carbon material to form an evaporation chamber 76 and a melting chamber or area 78, interconnected by a sloping cross member forming a feed channel 80. The carbon body portion 82 forming the melting chamber 78 is heated by the inductive heating coil 84 connected to a suitable source of high frequency power. The heating is limited to raising the temperature of the melting chamber 78 for pre-melting only while limiting the evaporation to a minimum. The molten coating material drains down the feed channel 80 into the evaporation chamber 76 formed by the carbon container 86.

The container 86 and coating material are heated by the inductive heating coil 88 connected to a suitable high frequency power source. The coating material 89 is heated by the coil 88 to evaporate the material and emanate coating material vapors from the liquid vapor interface 90. The vapors from the material 89 are emanated upwardly in a vertical direction which is acceptable for most solid or sheet materials supported above the evaporation chamber 76. Thus, the alternate embodiment shown in Fig. 4 discloses a coating source for continuous feeding and is suitable in many instances where a conventional continuous coating source is desired.

I claim:

1. A coating source for continuously supplying molten coating material to an evaporation chamber and directing the vapors laterally from the chamber comprising a first carbon body having a recess formed in its upper surface for receiving molten coating material, a tapped counterbore projecting vertically and downwardly from the top surface of the recess, a central vertical column having an end secured in said counterbore and projecting upwardly, a second carbon body vertically spaced from the first body having a central chamber opening upwardly forming a melting chamber and a central bore projecting vertically from the lower surface for receiving said central column projecting from said first body, vertical channels formed in the second body and annularly disposed about the central bore and having inlets leading into the melting chamber for feeding material from the melting chamber and outlets over the recess in the lower body to continuously supply molten material to said recess, and an inductive heating coil connected to a source of high frequency power for energizing the coil, said coil being disposed about both bodies for heating the upper body to melt the material disposed therein, and the lower body to evaporate the material received through the feeding channels from the melting chamber, said coil producing a field through the lower body and between said bodies to laterally compact the molten material in and above the recess to provide a vertically sloping liquid vapor interface of said molten material for emission of vapors laterally from said source.

2. Apparatus for evaporating metal in a vacuum, the apparatus comprising means forming an evaporation chamber including an upper confining wall and a lower confining wall, the chamber means being open on at least one side thereof, crucible means above the chamber means, means defining a passage extending from the bottom of the crucible means through the upper wall of the chamber means, means for melting the metal to be evaporated in the crucible means, the melted liquid flowing down the passage into the chamber, means forming a substantially vertical surface in the chamber, means for generating a high frequency magnetic field in which the lines of flux extend substantially vertically through the chamber, the high frequency magnetic field producing inductive heating of the liquid metal in the chamber to produce rapid evaporation of the metal in the chamber, the liquid being supported along said vertical surface in the chamber by the magnetic field to provide a vertically sloping liquid vapor interface in the chamber for lateral

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emission of the evaporated metal through the open side of the chamber.

3. Apparatus as defined in claim 2 wherein the means forming the vertical surface comprises a vertical column extending through the chamber, the chamber being open on all sides to permit lateral emission in all directions from the vertically sloping liquid-vapor interface formed by the liquid extending up the column by the action of the magnetic field.

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