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Van Poucke

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[54] **APPARATUS FOR VAPORIZING METAL ON A SUBSTRATUM**

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[52] **U.S. Cl.** **118/49.1**, 117/107.1

[51] **Int. Cl.** **C23c 13/12**

[58] **Field of Search** 117/107.1, 93.3; 118/49.1, 621, 50.1

[56] **References Cited**

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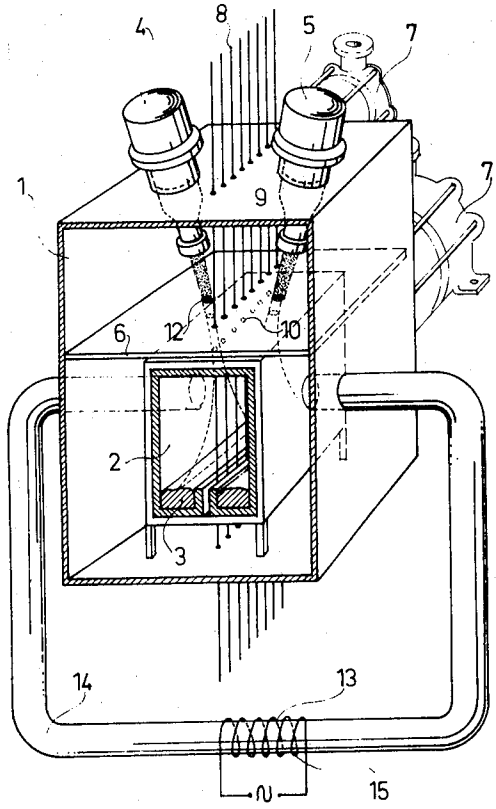
[57] **ABSTRACT**

A device and method for vaporizing metal onto a substratum in which the metal to be deposited on the substratum is maintained in a crucible under vacuum, an elongated substratum is passed through the vaporized zone, and the metal is vaporized by a strongly focussed moving electron beam from an electron gun and deposited on the moving substratum.

3 Claims, 5 Drawing Figures



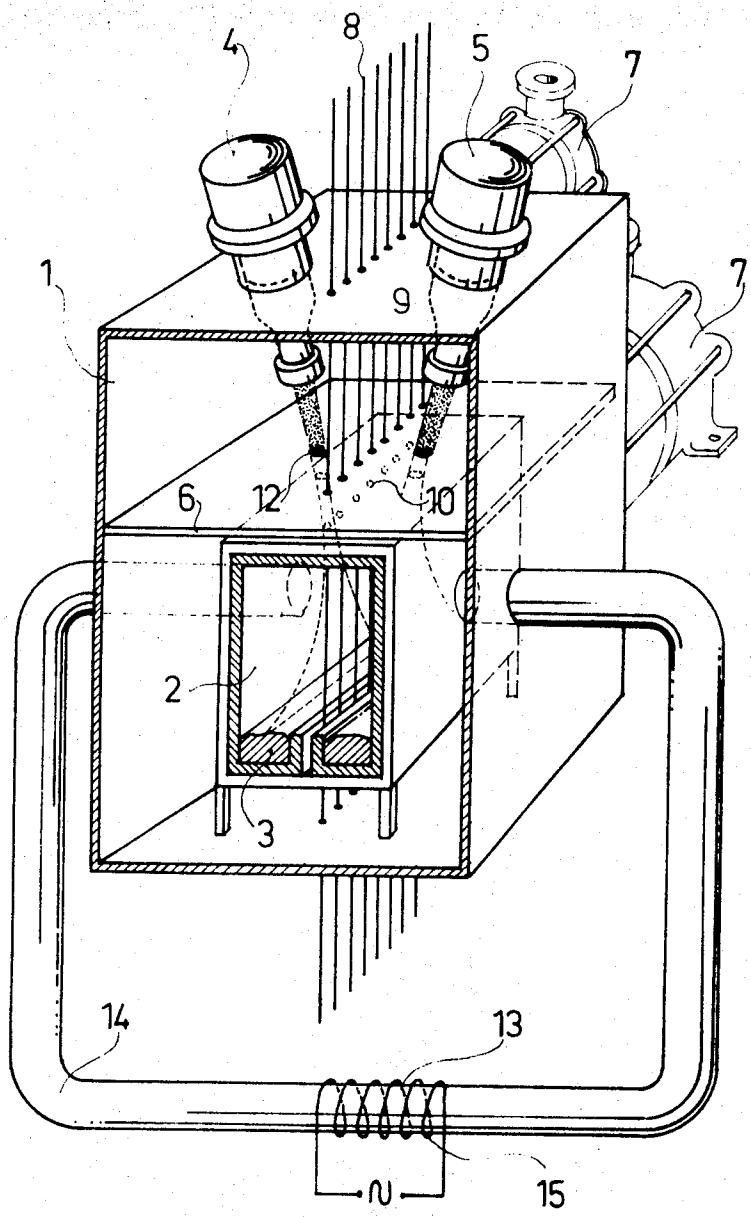


FIG:1

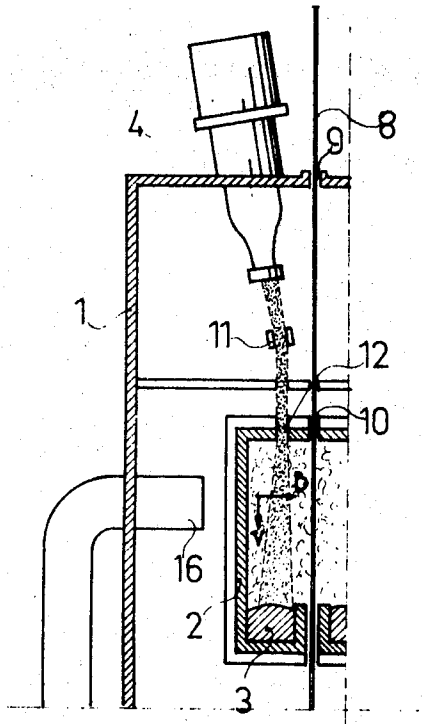


FIG: 2

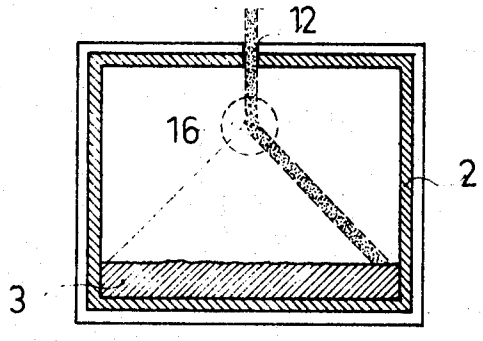


FIG: 3

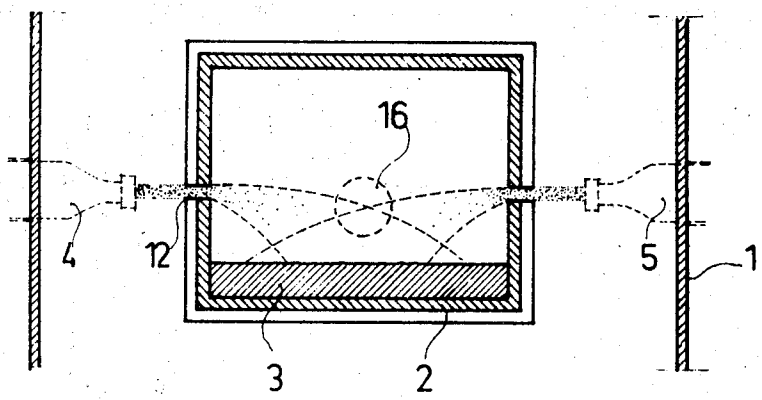


FIG. 4

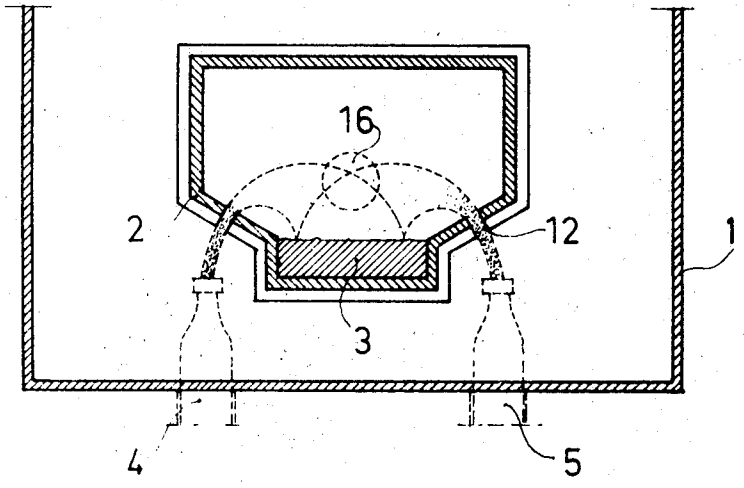


FIG. 5

APPARATUS FOR VAPORIZING METAL ON A SUBSTRATUM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an apparatus and method for evaporating metal for deposition as an outer layer or coating on a substratum. More particularly, the present invention relates to an evaporation device comprising a crucible with the metal to be evaporated, the device being provided with one or more electron guns, means for the continuous passage of at least one elongated or oblong substratum such as a hoop, strip or wire through the crucible and the evaporating device, and means such as vacuum pumps for creating the desired vacuum in the evaporation device and the crucible.

2. Description of the Prior Art

Devices for the evaporation of a metal employing electron guns for heating the metal and evaporating are known. The great advantage of the utilization of electron guns is that the choice of metals to be evaporated is practically unlimited. It is, indeed, possible to evaporate metals with a high boiling point with an electron gun. A further advantage of electron guns is that high energy densities can be obtained locally on the surface of the metal to be evaporated.

A big disadvantage of the prior art evaporation devices, provided with electron guns, is that their material output is low. The word output means here the ratio of the weight of the condensed metal vapor on the substratum to the weight of the condensed metal vapor on the substratum and the weight of the lost metal. The primary reason of this low output is the existence of an insufficiently closed crucible. Another disadvantage resulting from the existance of an insufficiently closed crucible is that it is very difficult to obtain a sufficiently high vapor pressure of the evaporated metal in the crucible or in the space above the metal to be evaporated.

Since a high vacuum, 10^{-4} Torr, for example, prevails in the space around the crucible, the evaporated metal will flow towards this space and precipitate on the walls of this vacuum space. The value of these leakage flows is, among other things, proportional to the surface of the apertures in the crucible and to the difference in pressure present. If it is now desired to coat an elongated substratum, e.g., a wire, with an outer layer of a given metal with a given thickness, this substratum should be moved at a given speed, dependent on the value of the vapor pressure in the crucible, through this crucible. It is clear that the lower the vapor pressure in the crucible, the lower the speed of the substratum through the crucible must be. Consequently, only low inlet speeds can be obtained with the devices as far known.

SUMMARY OF THE INVENTION

The present invention relates to apparatus and method for vaporizing metal onto an elongated substratum wherein the metal to be deposited on the substratum is maintained in a vaporization zone under vacuum in a crucible, the elongated substratum is passed through the vaporization zone, and the metal is vaporized by a moving beam of electrons from at least one electron gun and deposited on the moving substratum. More particularly, the evaporating device is characterized in that (1) each electron gun is provided with focussing elements such as magnetic lenses or coils, and/or means such as a high acceleration potential, for obtaining a strongly focussed electron beam, (2) the crucible is almost completely closed having only one small aperture per electron gun, whereby the distance between this aperture in the crucible and the focussing elements is determined in such a way that this aperture is located in or near the focus or focal point of the formed electron beam, and (3) means are provided to move the formed electron beam in the crucible at a suitable speed over the surface of the metal to be evaporated.

It is an object of the present invention to provide an apparatus and method for overcoming the disadvantages of the prior art techniques employing electron guns for vaporizing metals on a substratum.

A further object of the present invention is to provide an apparatus and method whereby practically no evaporated metal can any longer escape from the crucible via the apertures, through which the electron beam falls upon the metal to be evaporated in the crucible. In this way a big increase is obtained in the output, and it is possible to build up a high vapor pressure in the crucible resulting in high evaporation speeds.

A still further object of the present invention is to provide an apparatus and method whereby homogeneous outer layers or coatings are obtained.

Other objects and advantages of the present invention will become apparent from the following description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of one embodiment of an evaporation device constructed in accordance with the present invention;

FIG. 2 is a front view of a part of the device shown in FIG. 1;

FIG. 3 is a side view of the crucible of the evaporation device shown in FIG. 1;

FIG. 4 is a side view of a modification of the crucible shown in FIG. 3, with schematically reproduced electron guns; and

FIG. 5 is a side view of a further modification of the crucible shown in FIG. 3, with schematically reproduced electron guns.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The evaporation device consists of a chamber **1**, in which is placed a nearly completely closed crucible **2** holding the metal **3** which is to be evaporated. The crucible **2** has an inner lining made of fireproof material such as graphite, fireproof bricks, a refractory metal such as tungsten, tantalum, etc. which is not attacked by the molten metal. Around this inner lining an insulating jacket made of suitable material will eventually be placed. The shape of the crucible **2** will be preferably designed in such a way that the metal **3** to be evaporated is present in the crucible **2** around the substratum to be coated. This is of importance for the obtaining of a homogeneous layer, as with wires, sheeting, etc. It is also possible to provide means for a continuous supply of the metal **3** to be evaporated to crucible **2**.

In the upper surface of chamber **1** two electron guns **4** and **5** are provided, for instance. These guns have, for example, a capacity of 30 KW and a voltage of 60 KV.

The higher this voltage or acceleration potential with a given type of gun and capacity, the narrower the electron beam emitted. The guns are connected with chamber 1 in such a way that they form part of the chamber. Chamber 1 may possibly be divided into two spaces by means of a partition 6, in which respectively the guns and crucible are present. Vacuum pumps 7, which are connected with these spaces, serve to create the desired vacuum in these spaces of chamber 1, i.e., 10^{-4} Torr for instance.

The crucible walls will be heated by back-scattering of the emitted electrons as well as by the formed hot metal vapor, with the result that the evaporated metal falling thereon condenses to a liquid which flows back into the crucible or else re-evaporates. If re-evaporation is to be obtained, it is likewise possible to bring the crucible to the required temperature from outside by known means.

By means (not shown) such as with winding coils driven at an appropriate speed and loose unwinding coils, the elongated or oblong substrata 8 to be coated, such as wires, strips, etc. can be moved through chamber 1 and crucible 2. For this purpose a plurality of appropriate inlet apertures 9 and 10 are provided in the crucible and chamber. The dimensions of these apertures are very small and adapted to the measurements of the substrata to be covered. Leading elements (not shown) ensure that the substrata are practically unable to make any lateral motions during the passage through the crucible 2 and chamber 1.

Focussing elements such as magnetic lenses 11 (see FIG. 2) serve to strongly focus the electron beam emitted by the guns. The supply current in these magnetic lenses or coils can be changed in order to alter the focussing of the beam. It is also possible to provide additional focussing lenses in the head of the electron guns.

Crucible 2 has only one small aperture 12 (see FIG. 2) per electron gun. The distance between this aperture 12 in the crucible 2 and focussing element 11 and the supply current in these elements 11 is determined in such a way that this aperture 12 is located in or near the focus or focal point of the formed electron beam. The term focal point or focus here refers to the point where the formed electron beam is most strongly clustered. Obviously, this does not refer to a geometric point. It is indeed possible and even desirable for the electron beam to be clustered by means of appropriate magnetic lenses 11 over a certain distance between the electron gun and the surface of the metal to be evaporated. Aperture 12 can thus be restricted to a minimum, i.e., a round aperture with a diameter of, say 5 mm. It is also possible for the electron guns to be mounted at another point than in the upper surface of chamber 1 (see FIGS. 4 and 5) and for the emitted and formed electron beam to be deflected electrostatically or magnetically in a suitable manner to aperture 12 of crucible 2.

This strongly focused electron beam with its high capacity touches the metal 3 to be evaporated only on a very small portion of its surface at any one time. It is therefore necessary that the device be provided with means for moving this formed electron beam in crucible 2 with sufficiently high speed over the surface of the metal 3 to be evaporated.

In order to move this electron beam in crucible 2 over the surface of the metal 3 which is to be evaporated at suitable speed, the device is provided, according to the present invention, with a magnetic chain 13. This chain 13 consists of an unclosed core 14 of ferromagnetic material. A conductor 15 is wound around part of this core 14 and is connected to a source of alternating current and this source creates a current which can be controlled in amplitude and frequency. Crucible 2 is mounted beeen the extremities or pole shoes 16 of this magnetic chain 13 (see FIG. 2). The material of the walls of chamber 1 and crucible 2 may not be ferromagnetic material nor may they show any ferromagnetic properties during the utilization of the device. This is essential in order that the lines of force running in the magnetic chain 13 may close themselves in the space above the metal to be evaporated.

If an alternating current is now passed through coil 15, an alternating magnetic field, which may be termed "B," will be produced between the extremities or poles 16 of core 14 or in the space above the metal 3 to be evaporated in crucible 2. The value of the magnetic field B depends, among other things on the magnitude of the current in the coil or conductor 15. The electron beam entering the crucible is now subjected to this alternating magnetic field. With the embodiments shown in the figures, the direction of magnetic field B between poles 16 is perpendicular to the motion direction v of the electron beam formed. If a charged particle Q at a given speed v enters this alternating magnetic field B the direction of which field B is perpendicular to the motion direction v, then particle Q is submitted to a force $F = B.Q.v$, whereby the direction of force F is perpendicular to the surface of vector B and direction of motion v. Since force F is always perpendicular to motion of direction v, the charged particles of the formed electron beam, will describe a curved path over the surface of the metal 3 to be evaporated. Because an alternating field B is now utilized, this path becomes alternately traversed in either direction. The frequency with which this path is traversed is determined by the frequency of the current in conductor 15, which amounts preferably to 50 hertz.

The great power of the strongly focussed electron beam is in this way evenly distributed over the surface of the metal to be evaporated. Clearly, by adjusting the magnitude of the current in conductor 15, field B and hence force F can be changed. Thus FIG. 3 shows clearly that the beam is oscillated back and forth over the entire surface of the metal 3 to be evaporated.

FIGS. 4 and 5 show two variants. Here it is essential that the beam entering the crucible be first deflected over 90° and 180°, respectively, in order to reach the surface of the metal 3 to be evaporated. This can be realized by means of permanent magnets for instance. It is also possible to provide chain 13 with means, such as a conductor wound around core 14 connected with an adjustable direct current source so as to excite an extra magnetic field in the crucible above the metal to be evaporated. A further possibility consists of sending an alternating current into conductor 15, which is superimposed on a direct current. Many known electronic arrangements can be utilized for this purpose. In order to check whether the incident and alternately moving electron beam touches the metal to be evaporated in crucible 2, it is recommended that chamber 1 and crucible 2 are provided with apertures that can be closed.

Another means of distributing the power supplied via the electron beam evenly over the surface of the metal 3 to be evaporated consists in defocussing or dispersing the electron beam in the crucible, for instance, by ex-

citing a dispersing field in the crucible, although this is much more difficult to carry out.

Inasmuch as the present invention is subject to many modifications, variations and changes in detail, it is intended that all matter contained in the foregoing description of the preferred embodiments or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. An apparatus for vaporizing metal on a substratum which comprises

a chamber,

at least one electron gun adapted to provide an electron beam for vaporizing a metal in a vaporization zone and disposed in said chamber external to said vaporization zone,

means for maintaining said chamber under a vacuum,

an enclosed crucible adapted to hold said metal to be deposited on a substratum and to provide said varporization zone, said crucible being tightly sealed and provided with one restricted aperture per electron gun to maintain a high metal vapor pressure in said vaporization zone in said crucible,

means for moving at least one elongated substratum through said vaporization zone by providing at least two apertures in said crucible, said apertures adapted to the measurements of said substratum in order to maintain a high metal vapor pressure in said vaporization zone in said crucible,

an electromagnet adapted to move said electron beam back and forther in said crucible over the surface of the metal to be vaporized, said crucible being located between the poles of said electromagnet, and

a magnetic lens adapted to focus said electron beam, the distance between said restricted aperture in the crucible and said magnetic lens for focussing said electron beam being such that said restricted aperture is located at approximately the focal point of said electron beam, said restricted aperture being adapted to the focal point measurements of said electron beam.

2. The invention as defined by claim **1** wherein the electromagnet includes means for providing a magnetic alternating field adjustable in amplitude and frequency in the crucible above the metal to be evaporated.

3. The invention as defined by claim **1** wherein the electromagnet includes means for providing a magnetic field adjustable in amplitude in the crucible above the metal to be evaporated.

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