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H. P. KUEBRICH ET AL

3,068,337

VAPORIZER AND METHOD FOR MAKING THE SAME

Filed Dec. 5, 1958

FIG. 1.

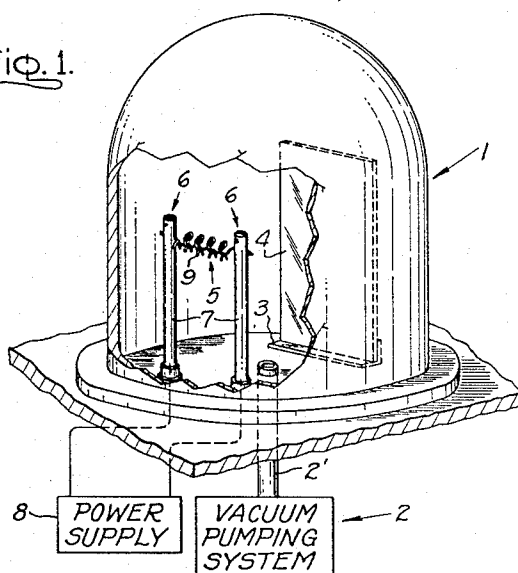


FIG. 2.

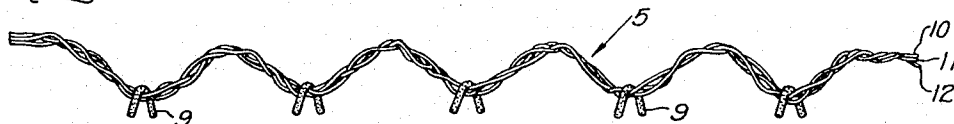


FIG. 3.

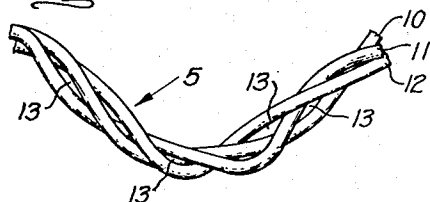


FIG. 4.

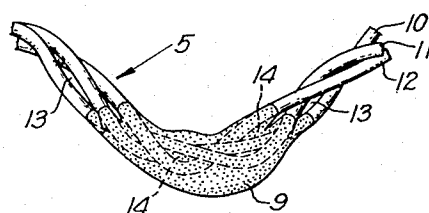
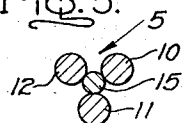


FIG. 5.



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VAPORIZER AND METHOD FOR MAKING
THE SAMEHerbert P. Kuebrich, Wickliffe, and Melvin L. Stone, East
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4 Claims. (Cl. 219-19)

The present invention relates to the coating of articles by vacuum thermal evaporation of metals with condensation of the metal vapors on the articles. The coating process is known commercially as vacuum coating or vacuum metalizing.

The apparatus used for the vacuum coating of articles consists essentially of a chamber which can be evacuated, a vaporizer for the metal to be evaporated mounted within the chamber and a support for holding the articles to be coated in position to receive the vaporized metal travelling in straight lines in the evacuated chamber from the vaporizer to the articles to be coated. In commercial installations the chamber and the support for the articles are of many different forms for coating articles of different sizes and shapes.

A common form of metal vaporizer used in connection with a large variety of coating chambers and article supports is an electric resistance heater which consists of a tightly twisted strand of refractory wires, such as tungsten wires. The tightly twisted strand is helically coiled along the greater part of its length and is provided with straight end portions for mounting on electrical conductor supports. A strand of this kind is shown and described in "Procedures in Experimental Physics," Strong, Prentice Hall Inc., New York, 1939, pages 171-180.

As compared to a vaporizer consisting of a single wire, the tightly twisted strand of wires provides spaces in the form of crevices and the like between the wires, into which spaces the charge of metal to be vaporized flows when heated to a molten condition. This increases the weight of the metal to be vaporized which can be used on the vaporizer.

Tungsten wire has been used for the strand when aluminum metal is to be vaporized. A three-wire tightly twisted strand of this kind is mounted in a horizontal position between spaced conductor supports and U-shaped clips or loops of aluminum metal wire are hung on turns of the helically coiled part of the strand. The aluminum metal pieces are heated on the strand in an evacuated chamber by passing an electric heating current through the strand to cause first the aluminum to become molten and, in its molten state, to wet, adhere to, and spread out by capillary action over the surfaces of the strand until the exposed tungsten wire surfaces of the strand are covered with molten aluminum. By continued passage of electric current through the strand the molten aluminum is caused to evaporate from the strand and the vapor thereof to deposit upon the surfaces of the articles to be coated in the vacuum chamber.

The strand is capable of reuse in this manner but its useful life is limited because, due to the reaction of tungsten with molten aluminum, the wires of the strand are eroded and break to terminate the useful life of the vaporizer.

Heretofore under average conditions commercial vaporizers of this tightly twisted structure have been capable of being recharged with aluminum and used about ten times on the average before being replaced by an unused vaporizer. Several millions of such vaporizers are used annually by the industry. Replacement of the vaporizer is

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an expense which includes not only the cost of the new vaporizer, but also labor cost for making the replacement and the downtime of the coating apparatus while replacements are made.

Obviously, if the useful life of the vaporizer is increased considerable savings can be made and the principal object of the present invention is to effect such savings by providing a stranded vaporizer of different structure from that described above and of longer useful life when used in place of vaporizers of the above type in existing vacuum metalizing apparatus for coating articles by the process of vacuum thermal evaporation of metals and condensation of metal vapor on the articles. Another object of the invention is to provide a stranded vaporizer on which the weight of a charge of metal to be vaporized can be approximately double the weight of a charge of such metal which can be used on commercial metal vaporizers of this type. Further objects and advantages of the invention will appear from the accompanying drawing, the following detailed description of species thereof and from the appended claims.

The invention attains its objects by increasing the exposed surface area of the wires making up the twisted strand without increasing the diameter or the length of the wires and by providing the strand with a hollow or open core extending along the entire length of the strand and with a multiplicity of interstices or small openings or gaps between the wires. As a result of the different structure of the strand the molten charge of metal to be vaporized spreads out more smoothly and quickly over the strand and coats the wires more uniformly and a heavier charge of metal to be vaporized can be used because the open structure of the strand of the present invention has a wick-like effect on the molten metal of the charge.

In the drawing accompanying and forming part of this specification:

FIG. 1 is a diagrammatic schematic, partly sectional view of a coating apparatus of well known structure in which a vaporizer embodying the invention is mounted,

FIG. 2 is an enlarged, side elevational view of a vaporizer embodying the invention and similar to that shown in FIG. 1,

FIG. 3 is a similar view on a further enlarged scale of a portion of the vaporizers shown in FIGS. 1 and 2 and showing the interstices between the wires,

FIG. 4 is a view similar to FIG. 3 showing the aluminum of one of the aluminum clips shown in FIGS. 1 and 2 in a molten condition and spreading out over the loosely entwined wires of the vaporizer, and

FIG. 5 is a transverse sectional view of the vaporizer at an intermediate stage of its manufacture.

Referring now to FIGS. 1 and 2 of the drawing, the apparatus in which the vaporizer is used, exemplified by the vacuum type housing 1 defining therein a vacuum coating chamber is arranged to be evacuated by a vacuum pumping system 2 through conduit 2'. The housing 1 has a support 3 therein for an article 4 to be coated by metal vapor. The vaporizer is shown at 5 and is described below. The vaporizer is clamped, as shown at 6, at its straight ends in the slotted ends of the electrical conductor supports 7. The supports 7 extend through the wall of the vacuum chamber and are connected to an electric power supply 8. Clips 9 of the metal to be evaporated are shown in place on the vaporizer 5 for being heated thereby.

With the clips 9 in place on the vaporizer and the article 4 to be coated located in the chamber the latter is first evacuated by the system 2 and then electric heat-

ing current is passed through the vaporizer 5 by the power source 8. The clips 9 thus are heated in a vacuum to cause the metal thereof first to become molten and spread out over the vaporizer and then to evaporate therefrom as described above. The heating current is increased after the molten aluminum has spread out over the vaporizer to cause quick evaporation. The metal vapor condenses on the article 4 to coat the latter.

The above described structure and operation of the coating apparatus is well understood in the art and additional description thereof is not necessary for a complete understanding of the present invention.

In accordance with the present invention the vaporizer 5, when used for vaporizing aluminum metal, is a helically coiled strand made up of three tungsten wires 10, 11 and 12 of the same diameter and loosely entwined. The strand has a multiplicity of interstices or small openings or gaps 13 between the individual wires as shown in FIG. 3 and has a hollow or open core as described hereinafter.

The loosely entwined wire structure of the strand of the vaporizer 5 provides a larger exposed surface area on each wire for the molten aluminum of the clips 9 to wet, adhere to, spread out over and vaporize from than does the present commercial form of vaporizer consisting of a tightly twisted strand of wires when both strands are made up of the same number of wires having the same diameter and length.

Further, the holding power of the vaporizer 5 for the molten aluminum, that is, the weight of aluminum which can be used without the formation of globules of molten aluminum, is greater than the holding power of the present commercial vaporizer due to the open core and the large number of interstices or small separate gaps 13 between the wires 10, 11 and 12 of the strand. Thus, as the clips 9 are heated and the aluminum becomes molten the molten metal flows into the open core of the strand and the gaps 13 between the wires at the part of the wires engaged by the clips. The surface tension of the molten aluminum and the adhesion of the molten aluminum to the surface of the tungsten wires hold the molten aluminum on the vaporizer against the forces of gravity. As a result of the combined action of the surface tension of the molten aluminum and its adhesion to the tungsten wire surfaces the molten aluminum tends to fill the open core and the gaps between the wires at the part of the vaporizer engaged by the clips 9.

As the molten aluminum spreads out over the surface of the tungsten wires as a result of capillary action it tends to collect in and fill also the other parts of the open core and the other gaps 13 in the vaporizer, as shown at 14 in FIG. 4. The exposed surfaces of the tungsten wires are quickly covered by the molten aluminum and the gaps between the wires are either partially or completely filled with the molten aluminum depending upon the size and shape of the gaps.

The vaporizer 5 of open structure thus has a wick-like effect on the molten aluminum, which effect increases the weight of the aluminum that can be used on the vaporizer by preventing the molten aluminum from collecting in large globules that are difficult to vaporize due to the inability to concentrate sufficient heat into them and which globules may drop off the vaporizer and may not only be wasted but also, in some types of apparatus, drop on the articles to be coated and ruin such articles.

The presence of globules of molten metal on the vaporizer causes hot spots in the parts of the tungsten wires on either side of the globules which increases the rate of erosion of the tungsten wires by the molten aluminum at these parts to shorten the useful life of the vaporizer. Vaporizers embodying the present invention, by preventing the formation of such globules, have a substantially longer useful operating life than present commercial vaporizers consisting of a tightly twisted wire strand.

Vaporizers having an open structure in accordance with the present invention are readily manufactured by wind-

ing the wires 10, 11 and 12 around a core wire 15 (FIG. 5) to form a tightly twisted strand and, with the core wire in place, coiling a length of the strand around a mandrel to helically coil the part of the strand between its straight ends. The mandrel is then removed from the helically coiled structure and the core wire is then removed from the strand to leave the helically coiled strand of loosely entwined stiff wires shown in the drawing. The strand has an open core on removal of the core wire 15.

The use of a core wire in making the loose wire strand is advantageous in that it facilitates making the strand with a predetermined spacing between the individual wires 10, 11 and 12. Due to the stiffness of the tungsten wires, control of the spacing of the wires in the completed strand would be difficult without the use of such a core wire, particularly in coiling the strand around the mandrel as described above.

In the mass production of vaporizers embodying the invention, the wires 10, 11 and 12 and the core wire 15 are stranded to form an elongated continuous tightly twisted strand which is subdivided into suitable lengths. The lengths are then processed as described above to constitute vaporizers having the desired structure.

FIG. 5 of the drawing shows in transverse section a straight length of the strand before the length is wound around the mandrel and processed to form the vaporizer. As shown in this FIGURE the wires 10, 11 and 12 are spaced from each other by the core wire 15 at this stage of the formation of the vaporizer. If the core wire were removed from the strand with the latter in this straight shape and aluminum metal was heated on the strand until molten, the molten aluminum would coat the individual wires by capillary action and the molten aluminum in excess of that required to coat the wires would tend to fill the spaces between the wires. The excess molten aluminum would be held in the spaces between the wires by its surface tension.

Of course, molten aluminum is held by its surface tension in the crevices between the wires of a tightly twisted strand in which the individual wires are in contact with each other throughout their length. However, in such tightly twisted strands of three wires only three of such crevices are provided by the wires and these are on the outside of the strand. By separating the wires the number of crevices is in effect doubled and each is enlarged to substantially increase the weight of molten aluminum which can be held on the vaporizer by increasing the space available for receiving the molten aluminum.

In making a preferred form of vaporizer embodying the invention for use in the coating apparatus shown in the drawing for coating articles by the process of vacuum thermal evaporation of aluminum and condensation of aluminum vapor on the articles to be coated, three tungsten wires each 30 mils in diameter are helically wound on a molybdenum core wire 19 mils in diameter at two turns to the inch to form an elongated tightly twisted strand. The strand is then cut into straight lengths of about eight inches and the lengths are jig-formed into helical shape at the center thereof by use of a straight mandrel about one-fourth inch in diameter at about one turn to the inch. Five complete turns are made around the straight mandrel. The ends of the strand are straight and each are about one-half inch long. The mandrel is then removed from the coiled strand and the molybdenum wire core is dissolved out of the strand to leave a loosely twisted helically coiled tungsten wire strand of the form shown in FIGS. 2 and 3 of the drawing and described above. The overall length of the strand made in this manner is approximately six inches. The strand 5 shown in FIG. 1 is shown as having four turns for clarity of illustration.

When the core wire 15 is dissolved out of the strand, the three stiff wires 10, 11 and 12 are left entwined together in such manner that the strand is self-supporting without the core wire. When the strand including the

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core wire 15 is wound around the mandrel, as described above, the gaps between the wires 10, 11 and 12 are changed in size and are discontinuous so that when the core wire is removed the strand has a plurality of separate openings of various sizes and elongated shapes between the wires. Further, removal of the core wire leaves the strand with a hollow or open core into which molten aluminum may flow when the vaporizer is in use in the coating apparatus.

The multiplicity of openings between the individual wires of the strand and the hollow core of the strand give the strand a wick-like effect on the molten aluminum which promotes the uniform distribution of the molten aluminum on the strand and is advantageous for retaining the molten aluminum on the strand without the formation of large, difficultly vaporizable globules of molten aluminum at any part of the strand.

It has been found that the weight of aluminum which can be held by the loosely twisted strand of the vaporizer 5 without the occurrence of large globules of molten aluminum during the coating process is about double the weight it is possible to hold on a tightly twisted strand of wires 10, 11 and 12 of the same length and diameter as those making up the loosely twisted strand. For example, with a vaporizer made as described above using wires 10, 11 and 12 of 30 mils in diameter and a core wire 19 mils in diameter, which core wire 15 is of course removed prior to use of the vaporizer, the formation of globules of molten aluminum does not occur until the weight of the aluminum used is increased up to 1.3 grams. With a vaporizer of the same structure except that the core wire 15 is not used and the wires 10, 11 and 12 are tightly twisted together, globules of molten aluminum are formed when the weight of the aluminum is increased to 0.65 gram. Of course, with lesser weights of aluminum globules do not form in either case.

By increasing the holding power of the vaporizer for molten aluminum the frequency with which the vaporizer must be recharged with aluminum metal is reduced to increase the efficiency of the coating apparatus in which the vaporizer is used. Also the part of the heating cycle necessary for causing the aluminum to become molten and spread out on the vaporizer before its temperature is raised to the vaporization temperature of the aluminum need not be repeated as frequently. Obviously the increased holding power of the vaporizer 5 for molten aluminum makes possible the coating of articles of larger size than could be coated by vaporizers of the commercial form described above.

While a specific and preferred form of vaporizer embodying the invention has been shown in the drawing and described above, it will be understood that changes may be made therein without departure from the spirit and scope of the invention as defined in the appended claims, for example, the number of turns in the strand may be changed, the wires making up the strand may be changed in number and the dimensions of the wires as well as those of the core wire 15 used in the making of the strand may be changed provided the size of the openings or interstices 13 between the wires and the open core of the strand is such relative to the surface tension of the molten metal to be evaporated that the vaporizer has a wick-like effect on the molten metal supported thereby.

The following are given by way of examples of wire sizes suitable for making vaporizers by the method described above and embodying the invention.

A core wire having a diameter of approximately 19 to 23 mils, inclusive, is suitable for use in making a strand wherein the wires 10, 11 and 12 each have a diameter of approximately 25 to 30 mils, inclusive. In general, a core wire of a diameter within the range of approximately 7 mils up to approximately the diameter of the wires 10, 11 and 12 is effective for three wire strands in which the diameter of the individual wires of the strand

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is approximately 25 to 30 mils. When the strand includes four wires each having a diameter of approximately 25 to 30 mils a core wire slightly larger in diameter than that of the individual wires may be used, for example, the diameter of the core wire may exceed the diameter of the individual wires of the four wire strand by approximately 5 mils.

When the individual wires of the strand are approximately 15 to 20 mils in diameter, a core wire within the range of approximately 7 mils up to approximately 5 mils larger in diameter than the individual wires of the strand may be used when the strand consists of either three or four wires.

From the foregoing examples it is apparent that the invention is capable of variations in the number of wires in the strand, the size of the wires making up the strand and the size of the core wire with respect to the individual wires making up the completed strand while retaining the wick-like effect of the strand on molten aluminum. The wick-like effect of the strand on the molten aluminum is retained so long as the entwined wires making up the final strand are separated a sufficient distance from each other to define a multiplicity of separate interstices therebetween and the hollow or open core of the strand is small enough so that molten aluminum can be held in the interstices and in the opening at the core of the strand by its surface tension.

In addition, the core wire may consist of other metals such as iron, steel or copper which can be dissolved out of the strand after its final shaping; or vaporizable metals, such as hard drawn aluminum, may be used for the core wire which can be removed by vaporization after the strand is formed. When the core wire consists of such vaporizable metals the core wire can advantageously constitute the first charge of vaporizable metal for the vaporizer which may be recharged thereafter in the usual way. Further, the wires 10, 11 and 12 may be made of other metals, such as molybdenum, tantalum and the like for vaporizing different coating metals, such as copper and silver, which do not readily wet wires of tungsten. Platinum may also be used with the strand made up of the tungsten wires 10, 11 and 12 for coating articles by the thermal evaporation of metals.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. The method of increasing the holding capacity of a stranded coiled vaporizer of stiff metal wires wet by molten metal to be evaporated without increasing the size of the wires making up the strand which comprises the steps of first helically winding the wires making up the strand in spaced apart positions tightly on a core wire, then forming the tightly twisted strand into helical shape to entwine the wound wires with each other and make the strand self-supporting without the core wire, and thereafter removing the core wire to open the strand thereby providing between the entwined wires of the helically coiled strand openings adapted to be filled by the molten metal to be evaporated.

2. A vaporizer for evaporating metal in a vacuum chamber comprising a coiled strand of entwined stiff wires consisting of refractory metal of a kind wet by the metal to be evaporated, said strand being self-supporting and having along its length a multiplicity of openings between the entwined wires and being open at its core, the said openings and core being adapted to be filled by the molten metal to be evaporated.

3. A vaporizer for evaporating metal in a vacuum chamber comprising a coiled strand consisting of a metal wire core to be evaporated and stiff wires entwined together and tightly wound on the core wire and consisting of metal of a kind wet by the metal of a core wire, said strand on evaporation of the core wire being self-supporting and having along its length a multiplicity of openings between the entwined stiff metal wires the said openings

being adapted to be filled by molten metal of the core wire.

4. A vaporizer for evaporating metal in a vacuum chamber comprising a coiled strand consisting of a core wire of aluminum to be evaporated and stiff wires of tungsten entwined together and tightly wound on the core wire, said strand on evaporation of the core wire being self-supporting and having along its length a multiplicity of openings between the entwined tungsten wires, the said openings being adapted to be filled by the molten aluminum of the core wire.

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Holland: "Vacuum Deposition of Thin Films" (1956), John Wiley and Sons, Inc., New York (pp. 172 and 173 relied on).

Disclaimer

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Hereby enters this disclaimer to the terminal portion of said patent.
[*Official Gazette June 14, 1966.*]

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