April 17, 1945. L. GOLD 2,373,823

METHOD OF COATING

Filed June 18, 1942

FIG. 1

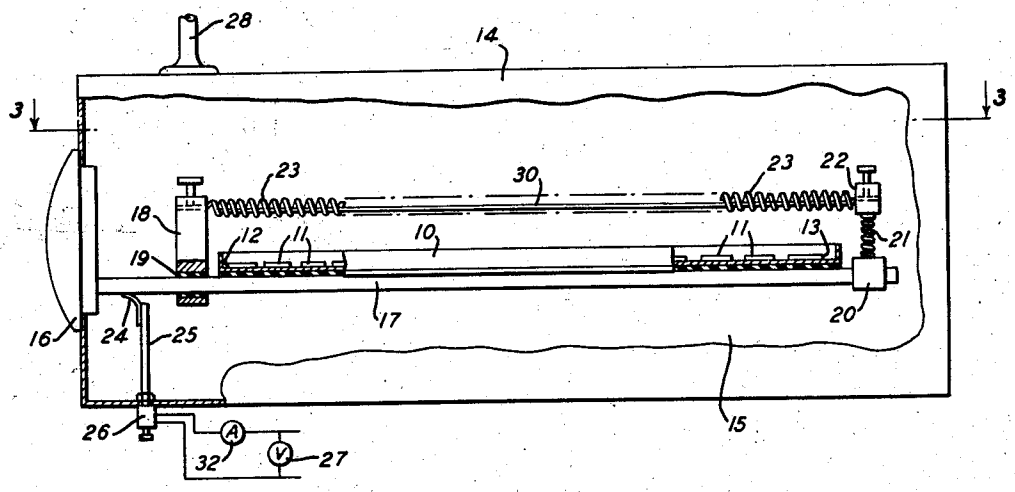


FIG. 2

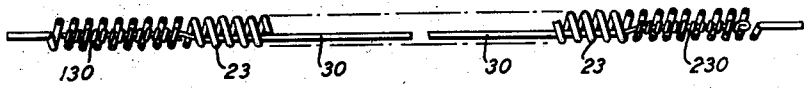


FIG. 3

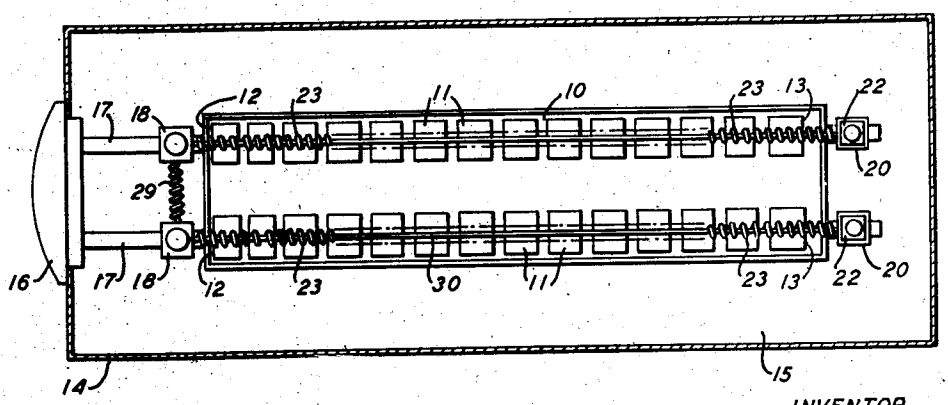
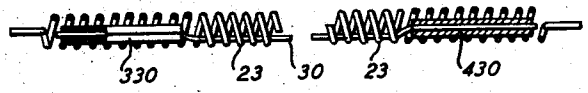


FIG. 4



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METHOD OF COATING

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4 Claims. (Cl. 117—35)

This invention relates to a method of coating, and more particularly to a method of coating a surface of a solid body with metal.

In various recent developments in branches of the electrical arts, it has become important to be able to provide accurately formed bodies of electrically insulating material, e. g. cut and polished slabs of crystalline silica or quartz or other crystalline non-conducting material, with a closely adherent deposit of metal of uniform thickness on one or more of the surfaces of such a slab, the metal coating so made being of uniform and closely predeterminable thickness and of uniform density.

An object of the present invention is to provide a method of forming a predeterminably thick coating of uniform thickness and density upon a surface of a solid body, with reliably constant results and simplicity of means and of operation.

With the above and other objects in view, the invention may be embodied in a method of coating the surface of a solid body with metal and comprising steps of distributing an elongated supply of evaporable metal adjacent to and parallel with a surface to be coated in such manner that the supply of evaporable metal is substantially constant in amount per unit length thereof except that the amount of supply per unit length is materially increased wherever the supply approaches an edge of the surface, and then enclosing the supply and the surface to be coated together in an evacuated space, and heating the supply to evaporate the same to coat the surface.

Other objects and features of the invention will appear from the following detailed description of one embodiment thereof taken in connection with the accompanying drawing in which the same reference numerals are applied to identical parts in the several figures, and in which

Fig. 1 is a diagrammatic view in side elevation with parts broken away, of an illustrative apparatus constructed to carry out the method in accordance with the invention;

Fig. 2 is an enlarged detached broken view in side elevation of a portion thereof;

Fig. 3 is a sectional view on the line 3—3 of Fig. 1; and

Fig. 4 is a modification of the showing of Fig. 2.

The apparatus herein disclosed to illustrate the method of the invention has for its purpose to form a film of metallic silver of uniform thickness and density upon one or a simultaneously coated plurality of slabs of crystalline quartz. To this end a rectangular tray 10, preferably of high heat resistant and electrically non-conducting material, e. g. ceramic material, heat resistant glass or the like, although the tray may also be of suitable metal provided on the under surface of its bottom with electrically insulating supports or an electrically insulating coating, serves to support the quartz slabs 11 to be coated with silver on their exposed upper faces. There may be a single slab 11 large enough to cover substantially all or a major portion of the floor of the tray; or, as illustrated, a plurality of slabs 11 to be simultaneously coated may be disposed on the tray floor preferably to cover substantially all of the floor, although fewer than this may also be treated at one time. For the purposes of the present invention, the upper surface of a single large slab occupying substantially all of the tray floor, or the combined upper surfaces of a plurality of smaller slabs simultaneously extending over substantially all of the floor surface, will be spoken of as the surface to be coated or treated regardless of whether it is actually one continuous surface or a mosaic of surfaces of a plurality of juxtaposed slabs. Similarly, when an end edge or the two end edges of the surface to be treated or coated are spoken of, such end edge is to be taken to mean the edge of a single large slab nearest to one end of the tray, or the combined colinear edges of a plurality of slabs nearest one end of the tray. Thus, as illustrated in the drawing, the surface to be coated or treated is the mosaic surface of all of the slabs 11 in the tray 10; and the two end edges of this surface are respectively the edges 12 and 12 taken together and the edges 13 and 13 taken together.

A horizontally elongated housing 14, having an evacuable chamber 15 therein, is rigidly supported in any suitable manner (not shown). Preferably, as illustrated, this housing and chamber are cylindrical, although they may have any suitable form. At the front or left end of the chamber is an opening closed by a removable and hermetically sealable door or plug 16. Rigidly secured in the inner face of the door 16 is a pair of parallel, horizontally extending, rigid bars or rods 17. These rods are preferably of electrically conductive and rigid metal, steel, hard brass, bronze or the like; and the door or plug 16 is preferably of insulating material, e. g. porcelain or other ceramic material. The door 16 may also be of suitable metal however, in which case the rods 17 must be electrically insulated from the plug or door where they are mounted in it. The bars 17 are spaced apart a suitable distance to allow the tray 10 to be placed and safely supported thereon. Twin binding posts 18 of elec-

trically conductive metal are rigidly mounted respectively on the bars 17 near their left or front ends, and are electrically insulated from the bars by sleeves 19 of ceramic or other suitable material. Twin metal blocks 20 are mounted respectively on the bars 17 and in electrical contact therewith near the right or rear ends thereof. The blocks 20 are so spaced from the posts 18 as to receive the tray 10 easily therebetween. On each block 20 is a vertical, laterally resilient upright support 21, e. g. a vertical helix of stainless steel or other suitable electrically conductive metal. On the top of each support 21 is secured a metal binding post 22. The horizontally disposed wire receiving bores of the four clamping heads of the binding posts 18, 18, 22 and 22 are all substantially equidistant from the plane of the floor of the tray 10 when the tray is in place on the bars 17.

A wire helix 23 is clamped in and extends between each binding post 18 and the binding post 22 mounted on the same bar 17. Thus, in the illustrated apparatus, there are two helices 23 supported parallel to each other and above and parallel to the floor of the tray 10 on the bars 17.

All the dimensions of the apparatus as thus far described will vary with the size of the surface to be coated and must be determined accordingly. In one particular instance of actual practise, the surface to be coated was approximately eleven inches long by three inches wide and was a mosaic of the surfaces of a plurality of quartz crystal slabs covering substantially the entire floor of the tray 10. The helices 23 were about thirteen and one-half inches long between binding post centers and were located about three inches apart and two and one-half inches above the surface to be coated. Each helix was a molybdenum wire about 0.02 inch in diameter, with about twelve and one-half coils to the inch and an internal diameter of its coils of about one-sixteenth of an inch.

Resilient contact members 24 carried on binding posts 25 suitably mounted in and passing through the wall of the chamber 15, make resilient electrical contact with the bars 17. The clamping heads 26 of the posts 25 outside the housing 14 are connected to a source of electrical power (not shown) and also to suitable voltage and amperage indicating devices 27 and 32 respectively. An exhaust pipe 28 communicating through the wall of the housing 14 with the chamber 15, is connected to some suitable evacuating device (not shown).

Before the helices 23 are secured in position, as shown, in the binding posts 18 and 22, there is threaded into the cylindrical axial space of each helix an elongated body of silver to be the supply of silver to be evaporated and deposited upon the surface to be coated.

The obvious way to do this is to cut a piece 30 of silver wire equal in length to the distance between the end edges of the surface to be coated and then to insert such a piece of wire into each of the helices 23.

The chamber 15 is then evacuated, current is supplied to the helices 23 to heat them, through the contacts 24, and the silver wire heated by the helices is evaporated or sublimed and deposits a coating of silver on the surface in the tray 10 below.

If the procedure be undertaken in this manner, it is found that, with the helices 23 suitably disposed over the surface to be coated as to distance from the surface and distance from each other and from the side edges of the surface, the surface is satisfactorily coated over its entire extent except for a transverse strip adjacent each end edge of the surface where the coating thins progressively toward each end edge. The width of this strip varies somewhat with varying proportions and dispositions of the parts, but seems to be always of materially important extent and represents an annoying and even costly waste of both silver and crystal slab. It may, of course, be obviated by making the length of the helices 23 and of the silver wire therein enough greater than the distance between the end edges of the surfaces to be coated to ensure that the insufficient coating effect is wasted beyond the end edges. However, this is not only a costly waste of silver, but also tends to build up encrustations of silver on the bars 17 and even perhaps to solder these bars to the contacts 24.

In accordance with the present invention, it has been discovered that a uniform coating from end edge to end edge of the surface to be coated can be effected, with negligible waste of silver beyond the end edges, if the silver supply, substantially constant elsewhere per unit length, be materially increased over the portions of the surface to be coated near each of its end edges, apparently over a distance comparable to the width of the transverse strips insufficiently coated by a completely uniform supply. In accordance with the invention therefor, the silver supply wire 30 is made about equal in length to the distance between the end edges of the surface to be coated but it is increased in mass near each end, either by winding a detached extra piece of the silver wire over a suitable length of the main silver wire as shown at 130 at the left end of Fig. 2, or by turning back and similarly coiling an undetached extra length as shown at 230 at the right in Fig. 2. Similarly, a bit of silver foil might be coiled on as indicated at 330 at the left in Fig. 4, or a sleeve of silver might be slipped on as shown at 430 at the right in Fig. 4.

The amount and distribution of the silver thus added to each end of the supply will vary from case to case; and the variables involved are too many for any practicable formula predetermining this to be given. However, in the particular case for which dimensions are given above, it was found that a coating from end edge to end edge of the surface to be coated and without materially important waste beyond these edges could be obtained by taking two extra pieces of the same silver wire as that used for the main supply wire 30, and winding one on each end of the main wire over a distance of about two inches, each of these pieces being about four and one-half inches long before winding. The silver wire used was substantially pure silver and about 0.01 inch in diameter.

In carrying on the coating operation, certain conditions of operation are found to be materially important. For instance, in the particular case already referred to, the following cycle of steps is preferred. The apparatus is arranged and prepared as already described and then is evacuated through the tube 28 until the pressure inside is of the order of 0.00001 mm. of mercury. Current is then applied to the contacts 24 and thus to the bars 17. This current flows from one contact 24, through the corresponding bar 17, block 20, resilient support 21, clamp 22, and helix 23, to one post 18. The two posts 18 are connected by a suitable conductor 29. The current flows through this to the other post 18 and

thence back via the other helix **23**, clamp **22**, support **21**, block **20** and bar **17** to the other contact **24**.

The current is so regulated that it increases gradually over a period of about five seconds to about five amperes and is held at this value for two minutes. In the next ten seconds it is brought up gradually to ten amperes.

At the beginning of these periods of current flow, the current flows through each molybdenum helix **23** and also through the silver wire **30—130** supported in the helix. The silver wire is not inserted into the binding posts; nevertheless it in effect short circuits the successive coils of the molybdenum helix and carries most of the current at first. The silver wire is thus overheated and fuses apart between coils of the helix. At each such breakage of the silver circuit an increase of voltage is registered on the voltage registering device **27**. The ten ampere value of the current is maintained until no further voltage increase is registered, showing that no helix coils remain shorted by the silver.

The dimensions of the helix **23**, especially the spacing between coils or pitch of the helix, but also the diameter of the molybdenum wire, are important. These must be such that when all the silver short circuits are fused and broken, the amount of molten silver associated with each helix coil will not be greater than the surface tension of the molten silver can retain attached and adherent to the coil, so that no gross droplets of molten silver will fall from the coil to coat the surface below irregularly and excessively. At the same time the helix coils must be as widely spaced as may be to minimize their interference with the evaporation or sublimation of the silver as vapor down upon the surface in a uniform manner. For the distance of the helices above the surface and from each other and for a 0.01 inch silver wire, the helix of molybdenum 0.02 inch wire, about twelve and one-half coils to the inch, and with an internal helix diameter of about 0.065 inch, is found to be satisfactory. If a greater or less volume of silver per unit length of helix is to be evaporated, the helix dimensions will be modified accordingly and also the amperages and lengths of time of the successive steps of the process.

The silver short circuits having thus all been broken, the amperage is reduced abruptly to about five amperes and held at that value for about five minutes to allow the silver to form itself into probably pastily soft, not fluidly molten, bodies on the helix coils. This is not a known fact, for observation of what happens in the chamber **15** is not practicable. At any rate, after the last jump in voltage value indicating the breakage by fusing of the last silver short circuit of helix coils, the silver is heated only by direct conduction from the electrically heated helix and not by the current directly.

After the five minute period at five amperes, the current is raised abruptly to ten amperes for twenty seconds, then to eleven amperes for twenty seconds, twelve amperes for twenty seconds, thirteen amperes for twenty seconds, fourteen amperes for ten seconds, and then abruptly down to zero.

This completes the actual process of coating. The vacuum inside is broken by admitting air through the tube **28**, and the door or plug with its rods **17** and tray **10** are removed.

While the particular case and apparatus described relate to the coating of silver on quartz slabs by silver evaporated from a supporting helix or helices of molybdenum, the invention is not so limited; other metals, e. g. aluminum, zinc, gold, tin, etc. may be used as the coating material in suitably modified apparatus and by the same general procedure, to coat other substances than quartz, e.g. high silica glass, mica, ceramic objects, slabs of almost any metal if desired, and other analogous surfaces. While molybdenum is the at present preferred material for the helices **23**, other metals, e.g. tungsten, may also be used. The preferred material for the helices will necessarily depend upon the nature of the coating metal. Preferably the material of the helix should not be materially affected or alloyed by the molten coating material, to enable re-use of any given helix as often as possible. Other modifications and variations of the particular illustrative embodiment above described within the spirit and scope of the invention as pointed out in the appended claims will readily occur to those skilled in the art.

What is claimed is:

1. The method of coating a surface having an end edge with a coating which is uniform to the said edge and which method comprises steps of positioning over and generally parallel to the surface to be coated a supply of evaporatable material in amount and distribution substantially constant per unit area of the surface except adjacent to any end edge of the surface and there materially greater in amount per unit area of the surface, and evaporating the material to coat the surface with the vapor thereof.

2. The method of coating a surface having an end edge with a coating which is uniform to the said edge and which method comprises steps of positioning parallel to the surface and at an angle to the end edge thereof an elongated body of evaporable material substantially uniform in amount per unit length except at any end thereof adjacent to an end edge of the surface and there of materially greater amount per unit length than along the neighboring portion of the body, and evaporating the material to coat the surface with the vapor thereof.

3. The method of coating a surface having an end edge with a coating which is uniform to the said edge and which method comprises steps of positioning parallel to the surface to be coated an elongated body of evaporable metal supported in a metallic helix, the said body being not parallel to the end edge of the surface and being of substantially uniform amount per unit length except at any end thereof adjacent to an end edge where the amount per unit length is materially greater than along the neighboring portion of the body, passing through the helix and the body an electric current of sufficient amperage to fuse the successive short circuits of the body from coil to coil of the helix, reducing the amperage of the current for a predetermined period to allow the fused and separated portions of the body to gather severally on the coils of the helix, and raising the amperage of the current to a sufficient amount and for a sufficient period of time to evaporate the metal of the divided body from the helix to the surface to coat the same.

4. The method of coating a surface which comprises steps of positioning parallel to the surface to be coated an elongated body of evaporable metal supported in a metallic helix, the said body being not parallel to the end edge of

the surface and being of substantially uniform amount per unit length except at any end thereof adjacent to an end edge where the amount per unit length is materially greater than along the neighboring portion of the body, passing through the helix and the body an electric current of sufficient amperage to fuse the successive short circuits of the body from coil to coil of the helix, reducing the amperage of the current for a predetermined period to allow the fused and separated portions of the body to gather severally on the coils of the helix, and raising the amperage of the current to a sufficient amount and for a sufficient period of time to evaporate the metal of the divided body from the helix to the surface to coat the same.

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