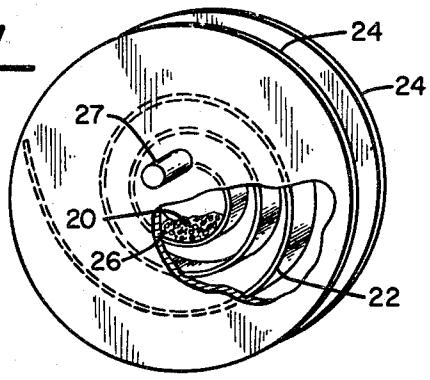
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SPIRAL VACUUM DEPOSITION APPARATUS AND METHOD

Filed Dec. 28, 1965

Fig. 1



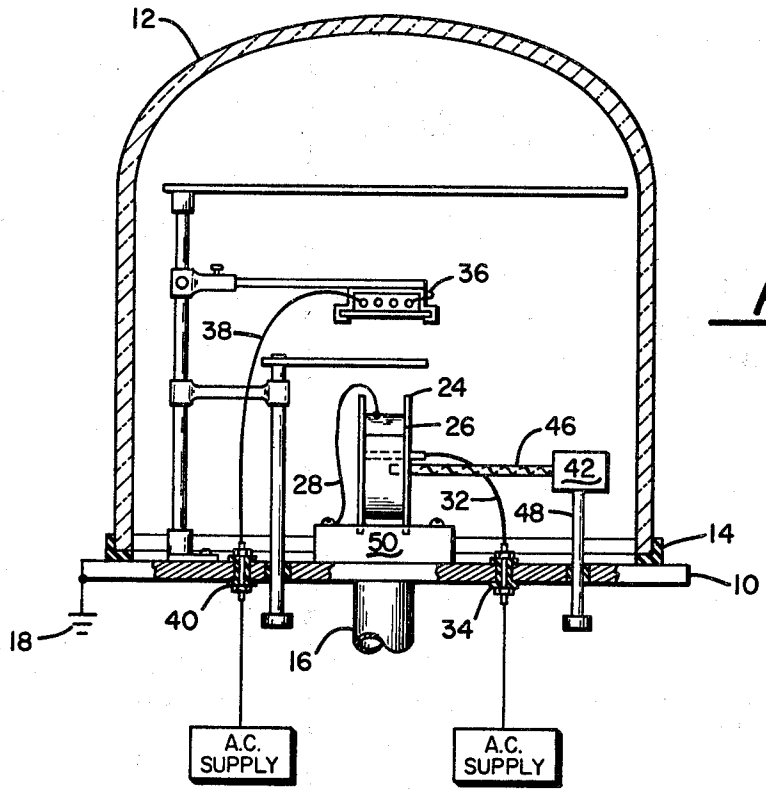




Fig. 2

INVENTORS
PAUL E. OBERG
MAYNARD C. PAUL

BY Joseph A. Spelich
AGENT

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# SPIRAL VACUUM DEPOSITION APPARATUS AND METHOD

Paul E. Oberg and Maynard C. Paul, Minneapolis, Minn. (both of Univac Park, St. Paul, Minn. 55116)

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The present invention relates generally to the evaporative fabrication of thin films in an evacuated chamber and more particularly to a method and apparatus for forming film electrical circuits.

The evaporative fabrication of a film of material within an evacuated chamber is a technique that has been recently employed in the electronics industry for fabricating electrical apparatus, such as, integrated circuits. Conventional integrated circuits usually are composed of several layers of electrically conductive films which in most instances are insulated from one another. Conventionally, the electrically conductive films and the electrically insulating films are formed within the evacuated chamber by vapor deposition techniques. Generally successful circuit design depends, to some degree, in each of the deposited layers having desirable uniform characteristics.

It has been found that when certain materials are employed to perform one or another of the conductive or insulating functions of these layers it becomes difficult to consistently attain films exhibiting the desired uniformity. A major difficulty results from the low thermalconductivity of certain non-conductive materials, such as silicon monoxide, which, when heated develop unevenly hot areas that result in spattering. Spattering is characterized by the sudden ejection from the material being evaporated of solid or liquid particles. Although metals do not generally exhibit the problem of spattering during thermal evaporation, some difficulty has been experienced when working with certain types of metals, for example, cadmium, zinc, and magnesium.

In the past, in order to reduce spattering, evaporation sources have been adapted to provide a structural arrangement for causing an evaporant to ascend to a substrate member by following a diverse path from its source. For effecting such diverse path, baffle plates have been interposed between the material in the evaporating container and the substrate upon which the evaporant is intended to be deposited. The baffle is effective to prevent the free flow of vapor between the baffle and the substrate by cutting off straight line paths between the material and the substrate. Spattering particles are trapped on the baffle surface whereupon they may be retained or subsequently re-evaporated therefrom. A baffle arrangement, however, for preventing the formation of non-uniform films, is often undesirable in that it can cause a reduction in evaporation rate and can become clogged by condensing vapor.

Accordingly, it is an object of the present invention to provide an improved method for evaporatively fabricating films of materials.

It is another object of the present invention to provide a method for re-evaporating an evaporant by the use of a curved heating source having a plurality of convolutions on a diminishing radius.

It is another object of the present invention to provide a spiral shaped ribbon evaporation source to accommodate re-evaporation of spattered evaporant particles along a tortuous path within the source.

It is another object of the present invention to provide apparatus for reducing the effect of source spattering upon the deposited film layers.

It is another object of the present invention to provide apparatus which is effective to reduce the effect of source spattering upon deposited films without impeding the evaporant path.



Still another object of the present invention is to provide a means for depositing uniform films wherein evaporant proceeds through a spiral shaped ribbon source and emanates therefrom free from any large particles.

The above and other objects are accomplished in accordance with the method and apparatus of the present invention wherein there is provided an evaporant source structure disposed in a vacuum chamber. A spiral shaped electrically and heat conductive ribbon source is enclosed by insulating side plates suitably supported by a support member. A center post provides a connection of the small radius tab end of the spiral and provides an electrical termination for connection to electrical ground. The other end of the spiral tab is connected to a power source. If desired, material to be evaporated may be supplied to the eye of the spiral through a suitable feed mechanism. The spirally wound ribbon is resistance heated above the evaporation temperature of the evaporant. Heat produced by the ribbon causes evaporation of the evaporant material which ascends following a tortuous path through the channel formed by the spiral ribbon. Solid or spattered particles ejected from the surface of the evaporating material are caused to impinge upon the spiral convolutions because of their straight line movement. Spattered particles are then re-evaporated and proceed toward the exit aperture of the ribbon. Emanating from the exit aperature will be an evaporant free of larger particles with the attendant uniform deposition of the evaporant material upon the substrate. The novel features of the invention, as well as additional objects and advantages thereof, will be understood more fully from the following description when read with connection with the accompanying drawings which:

FIGURE 1 is a side view of the evaporant source.

FIGURE 2 describes a vertical section of the vacuum enclosure incorporating the present invention.

By way of reference to FIGURE 2 of the drawings there is set forth the embodiment of the present invention incorporated within a vacuum enclosure or bell jar including a base plate **10** supporting the vacuum enclossure **12** which gasket member **14** forms an enclosure or chamber adapted to be evacuated by any suitable vacuum pump means (not shown) coupled to the apparatus of the pipe **16**. The base plate preferably, although not so limited, is constructed of stainless steel and electrically grounded at **18**. Conventionally, the base plate is constructed of a ridged material and the bell jar of glass. The material to be evaporated is subsequently condensed, that is for example, silicon monoxide melt **20** is contained in a continuous spirally curved ribbon container or source means **22**, which functions as a resistance heating element. The spiral is characterized by a plurality of convolutions on a diminishing radius. The source may be fabricated of a refractory material such as tantalum, however no limitation is intended thereby inasmuch as a variety of other suitable resistance heating materials may be utilized as well. In order to enclose the open sides of the helically wound resistance heater, for example, disc-shaped side plates **24** accommodate the continuous edges of the ribbon within a continuous groove or channel means formed in each of the end plates. The end plates are preferably constructed of fused quartz because of its excellent electrical and heat insulating characteristics and which will at the same time withstand the high temperatures encountered within the vacuum enclosure. However, no intention is made to limit the end plates to fused quartz inasmuch as a variety of materials exhibiting desired characteristics are suitable. An inherent advantage of the continuous groove **26** is that by its nature, the ribbon is permitted to expand and unwind when heated,

hence relieving additional stresses in the side plate channels. The inner tab of the ribbon 22 is secured to an electrically conductive tungsten post 27 passing through the disc-shaped side plates. Although the post 27 has been described as constructed of tungsten, no limitation is thereby intended since a variety of suitable materials may be used for the application. The post also functions as an electrical termination point for the ribbon. Energy is applied to the source by means of current flow through leads 28 and 32 respectively connected to the post 27 and the outer radius end of the spiral, lead 32 being connected by an insulating feed through 34 mounted in base plate 10 to a source of electrical potential externally located with respect to the vacuum chamber. Lead 28 is connected to ground 18 by way of the base plate 10. In a similar manner the substrate heater 36 is electrically coupled through lead 38 and insulating feed through 40 to an externally located source of potential, while the substrate support is mounted to the base plate which is connected to ground.

For those applications in which a constant source of melt material is desired, a feed mechanism 42 and auger 46 for example, are located within the vacuum enclosure. A drive mechanism 48 projects externally of the enclosure and is adapted for connection to a suitable driving means (not shown). The auger 46 conveys material from the feed mechanism 42 to the eye of the spiral and deposits melt material therein. The inherent advantage of this arrangement is that for long term deposition intervals, there will be insured a continuous supply of material for evaporation, without the necessity of breaking vacuum and resupplying the source with an additional charge of material to be evaporated.

A support means for the source is an insulator support means 50 disposed in the vacuum enclosure on the base plate 10. The insulator support means may take the form of two block members separated by a distance less than the diameter of the disc-shaped end plates thereby permitting the source to be mutually disposed upon the insulators. No intention, however, is intended to limit the support post to the particular configuration illustrated inasmuch as a variety of support means are suitable.

## OPERATION

After the pressure with the chamber has been reduced to a predetermined value, by means of the pump, energy is applied to the ribbon source by the current leads. The current flowing through the source supplies radiant heat to the melt. The current is adjusted to a level such that the melt within the source is heated to a temperature at which the melt material evaporates at the predetermined pressure within the chamber. When the desired evaporation temperature has been obtained, and it appears that such temperature has reasonably stabilized throughout the melt, a shutter member disposed in the alignment with the exit aperature of the source is rotated outside of the normal evaporant path and the evaporant is permitted to deposit on the shield disposed in the upper part of the evacuatable enclosure. The shutter member is mounted at one end upon the serrated gear portion, which gear portion is integral with the shaft projecting externally through a seal means of the evacuable enclosure. By applying a suitable force to the shaft of the shutter member, it is rotated outside of the evaporant path. Heat generated by the helical ribbon causes the material to evaporate in an ascending manner following a tortuous path through the channel formed by the helical ribbon and side plates. Solid particles ejected from the surface of the evaporating material are caused to impinge upon the ribbon convolutions due to their straight line motion. That is, the spiral is effective to interrupt and re-evaporate any larger particles impinging thereon, thereby preventing any larger spattered particles from escaping at the spiral exit. While following along the curved path of the channel the spattered particles are re-evaporated. As a result, an evaporant free of larger spattered particles is directed at the substrate. An attendant advantage of the present configuration is that radiation shielding is inherent in the utiiizaion of the helical source designed, that is, the rings formed by the tantalum ribbon enclosing the heat therein. For additional shielding, a circular shroud enveloping all but the source exit may be utilized if desired.

For application to a continuous vacuum deposition system, the feed mechanism is activated in order to supply an evaporant material to the eye of the helix, thus precluding the necessity of breaking the vacuum and reheating a new charge. Therein the rate of deposition and temperature of the evaporant during the process are maintained constant without experiencing the difficulties of recharging the source after each process. As a result thereof, the film deposited exhibits uniform characteristics.

Although the procedure outlined above may be employed for any evaporant material, it is particularly effective for the evaporation of electrical insulating materials. By way of example only, materials which may be employed include SiO and $M_gF_2$ which usually are available in powder form. In the fabrication of multilayer electrical circuits, it is necessary to employ more than a single evaporation source. One or more of these additional sources contain the materials for forming the required electrically conductive films and one or more of these sources contain the material for forming the insulating layer. Additionally, in order to form film layers in predetermined geometrical configurations, it is necessary to interpose one or more pattern defining masks intermediate the source structures and the substrate. The substrates are positioned with respect to any mask and evaporation source by some means, perhaps mechanical. The present invention is adaptable for use in the immediately aforementioned application.

As one alternative to the present invention, an all metal evaporation source may be utilized, thus eliminating the refractory side plates used with the present source. Where this alternative is exercised, RF heating may be used with significant advantages. In this aforementioned alternative adaptation, the side plates may be constructed of the same material as that of the ribbon heater, or may even be of different conductivity than that of the heater. Desired operating temperatures are determined by the thickness and resistivity of the material or materials utilized. Whatever materials are used, an outer reflecting shroud around the spiral minimizes heat loss. This feature applys equally as well to the invention illustrated in the drawings.

It is understood that suitable modifications may be made in the structure and method as disclosed provided that such modifications come within the spirit and scope of the appended claims. Having now, therefore, fully illustrated and described our invention, what we claim to be new and desire to protect by Letters Patent is:

1. A method of vacuum depositing material upon a substrate free of larger particles comprising the steps of:
   (a) subjecting an enclosed curved resistance heating element having a plurality of convolutions on a diminishing radius and containing a material to be evaporated to a source of energy in order to raise the temperature of said material to its evaporating temperature whereby said material is directed along the heating element enclosure in a tortuous path by impinging upon said element and being re-evaporated therefrom as the evaporant proceeds toward an exit.

2. A method for vacuum depositing evaporant upon a substrate comprising the steps of:
   (a) depositing a material to be evaporated into the eye of an enclosed source having a plurality of convolutions on a diminishing radius with an opening at one end thereof;
   (b) subjecting said material to a source of thermal energy;

(c) evaporating said material wherein larger particles of the evaporant are caused to follow a tortuous path along the convolutions whereby the particles impinging upon said convolutions are re-evaporated to prevent said particles from exiting through said opening but said evaporant continues through the opening to form a uniform coating upon the substrate.

3. A method of evaporating a body of material onto a substrate within an evacuated chamber and effective to evaporate said material uniformly onto the substrate without material spattering particles, which method comprises:

(a) subjecting said body to a source of thermal energy, said source being effective to uniformly increase the temperature of all of said body material to a temperature at which said material evaporates;

(b) said body temperature being raised by an electrical source of energy coupled to an electrical and heat conductive spiral having a plurality of convolutions on a diminishing radius, said body of material being contained within an eye of the spiral;

(c) said spiral being further effective to interrupt and re-evaporate any larger particles impinging thereon, thereby preventing said larger particles from arriving at said substrate.

4. The method of claim 3, wherein a continuous supply of material is fed to the spiral by feeding into the eye of the spiral.

5. Apparatus for depositing films free of spattered particles onto a substrate comprising:

(a) an electrically conductive ribbon-like continuous heating element comprising a plurality of convolutions on a diminishing radius;

(b) a smallest convolution corresponding to an eye of the heating element containing an evaporant material;

(c) side plate support members enclosing edges of said convolutions to form an enclosed path along the convolutions to an exit.

6. The invention of claim 5 wherein said plate members are electrical and heat insulating members.

7. The invention of claim 6 wherein said plate members contain a continuous groove corresponding to said convolutions, each of said grooves being in a supporting relationship with respect to an edge of said ribbon.

8. The invention of claim 7 wherein the plate members mount an electrically conductive member for fixedly securing one end of said ribbon.

9. The invention of claim 8 including:

(a) an evacuable enclosure for containing said apparatus;

(b) a power source disposed externally of said enclosure, said power source being coupled to said ribbon and to said electrically conductive member.

10. The invention of claim 9 including a feeding means for supplying material to be evaporated to the apparatus.

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ALFRED L. LEAVITT, *Primary Examiner.*

A. G. GOLIAN, *Assistant Examiner.*