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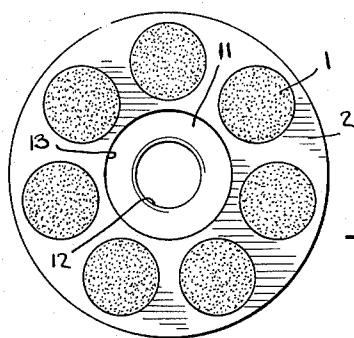
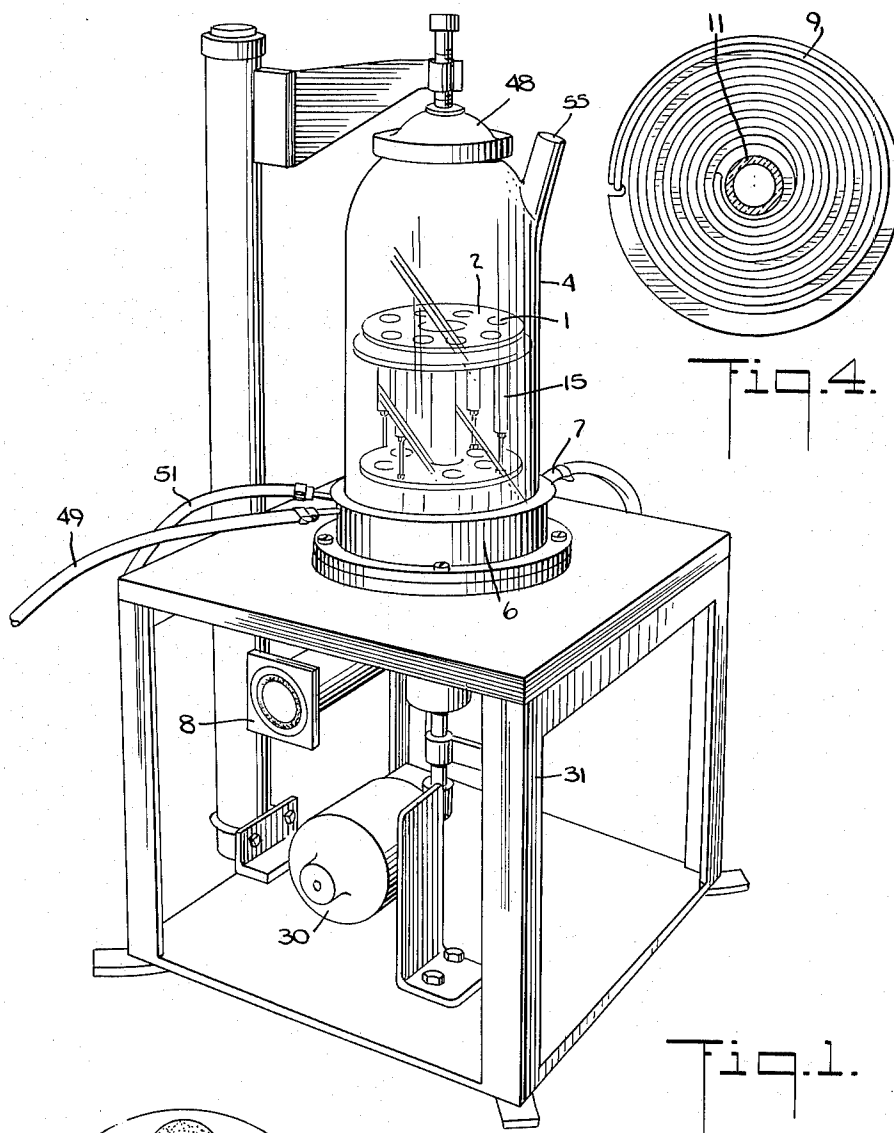
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APPARATUS FOR VAPOR PLATING

Filed April 23, 1962

2 Sheets-Sheet 1



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Fig. 2.

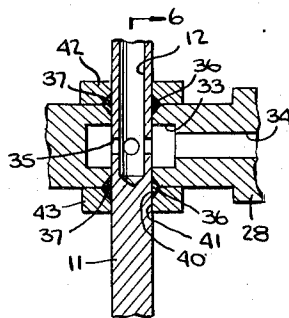
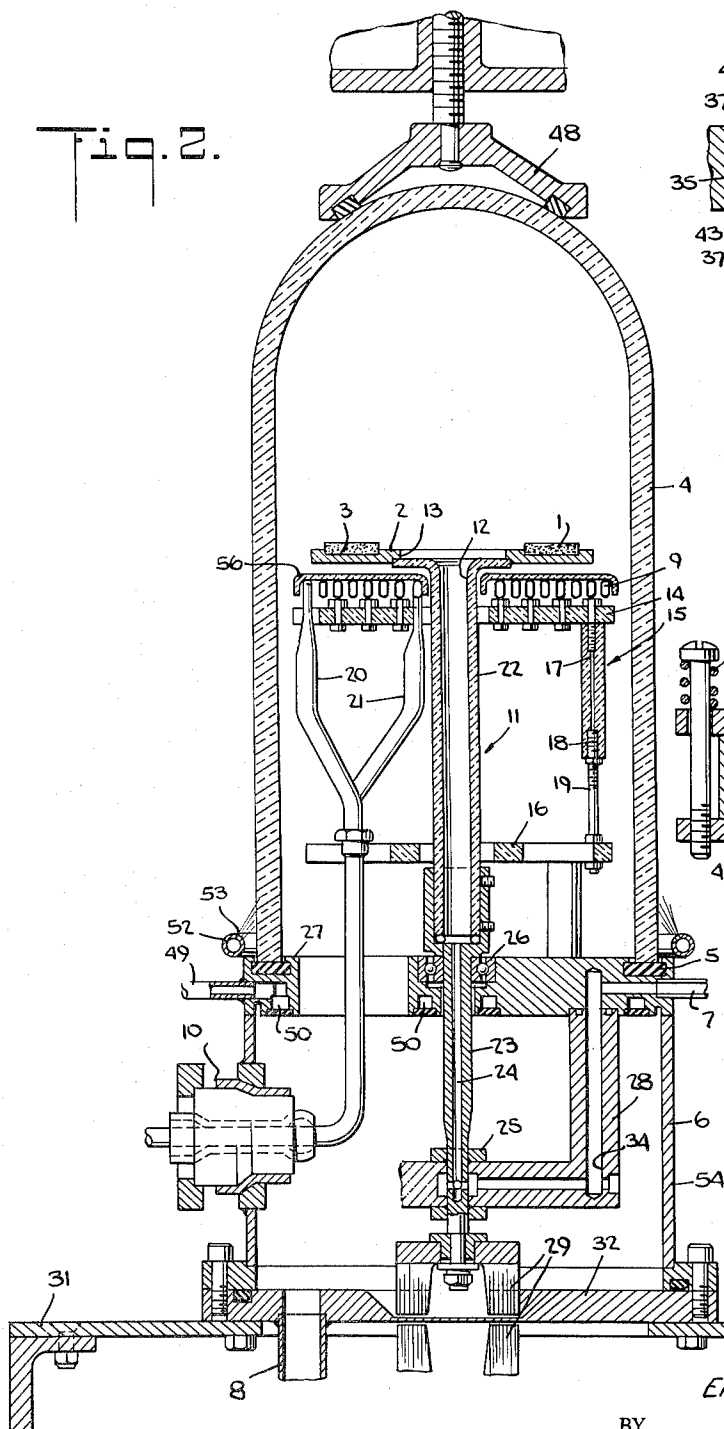


Fig. 5.

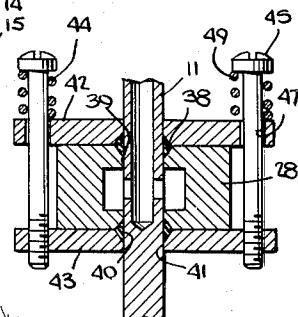


Fig. 6.

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APPARATUS FOR VAPOR PLATING
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The present invention relates to a method and means for vapor plating and more particularly to an improved vapor plating method and vapor plating furnace adapted to form a coating having a precisely controlled and absolutely uniform thickness and also being characterized by almost absolute purity.

In the well known vapor deposition coating processes, a volatile compound is reduced or decomposed on the heated surface of the object to be coated. In a hydrogen-reduction process, for example, hydrogen is passed over a liquid metal halide which is heated to provide a resulting mixture of hydrogen and the metal halide vapor. This mixture is passed into a coating chamber having a controlled pressure where it reacts at the heated surface of the object to be coated and deposits an adherent coating of the non-volatile reaction product.

The apparatus and method of the present invention represent an improvement in this general type of known process and apparatus wherein a uniformity of the coating thickness, an improved depth control, and a purity of the coating is obtained which has not been heretofore achieved.

Although the apparatus and method are useful for a variety of vapor plating operations and with a variety of plating materials, one important use is in applying silicon coatings to silicon discs such as are used in the manufacture of transistors where a silicon disc comprises the N-type and a silicon coating on the disc comprises the P-type. The uniformity of the coating thickness, the control of the coating depth, and the coating purity are of vital importance in this product and the apparatus and means of this invention meet these requirements so well as to provide a simpler and more reliable manufacturing operation and a better product. The apparatus and method will be described in connection with such a silicon coating operation although it is to be understood that they are not limited to such an operation and may be used with other coatings on other objects in a similar way.

As will be described more fully below, the method of the present invention and the apparatus for practicing the method provide a complete solution to the problems of uniform coating depth, coating depth control, and coating purity and permit the production of P-N type transistor elements with a degree of speed and reliability not heretofore obtainable.

Accordingly, an object of the present invention is to provide an improved apparatus and method for vapor plating.

Another object of the present invention is to provide a vapor plating furnace characterized by extremely accurate control of the plating thickness, a uniform coating depth at the desired thickness, and a purity of the coating.

Another object of the present invention is to provide an improved method and apparatus for vapor plating combining improved control with simplicity of furnace manufacture and operation.

Another object of the present invention is to provide an improved vapor plating furnace which is safely and efficiently operated by relatively inexperienced personnel.

Other and further objects of the invention will be obvious upon an understanding of the illustrative embodiment about to be described, or will be indicated in the

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appended claims, and various advantages not referred to herein will occur to one skilled in the art upon employment of the invention in practice.

A preferred embodiment of the invention has been chosen for purposes of illustration and description and is shown in the accompanying drawings, forming a part of the specification, wherein:

FIG. 1 is a perspective view of a preferred embodiment of the vapor plating apparatus of the invention;

FIG. 2 is a vertical sectional view of the vapor plating apparatus of FIG. 1;

FIG. 3 is a top plan view of the rotatable support for the articles being plated;

FIG. 4 is a top plan view of the induction heating coil;

FIG. 5 is an enlarged detailed sectional view of the rotating gland connecting the rotating article support with the source of gas and vapor; and

FIG. 6 is a vertical sectional view of the gland of FIG. 5 taken along line 6—6.

The improved coating apparatus or furnace will first be described generally with particular reference to FIGS. 1 and 2. As discussed above, the process will be described above, the process will be described in connection with the formation of a silicon coating upon silicon discs in the manufacture of P-N type transistor elements wherein the discs comprise the N-type and the silicon coating comprises the P-type. The silicon discs to be coated are illustrated at 1 arranged in spaced relation on the top of a circular support 2 which has spaced circular seats 3 provided to position the discs 1 uniformly around the support 2.

An air-tight chamber is provided surrounding the support 2 and comprising a removable cover 4 formed of a heat and corrosion resistant material such as quartz. The cover 4 is removably mounted by means of an air-tight seal 5 on a hollow and air-tight base 6. The gases used in the process to purge the air-tight chamber and the vapor plating mixture are admitted to the chamber through an inlet 7 in base 6 and an exhaust outlet 8 is provided to evacuate the enclosure and to withdraw the purging gases and the spent gases of the vapor coating mixture from the chamber. The discs 1 are raised to the reaction temperature before the vapor plating operation by an induction heating coil 9 mounted beneath the support 2 and coupled to a high frequency power source through the coupling 10 in the base 6.

In order to achieve the improved uniformity of the coating thickness, the improved control of coating depth and the improved purity of operation, a novel construction and inner-relation is employed for the support 2, the means for conducting the vapor plating mixture into the chamber from inlet 7, and the induction heating coil 9. These cooperating elements of the furnace will now be described in detail in connection with the application of a uniformly deep coating of silicon on the silicon discs 1.

The support 2 comprises a ring-like plate formed of molybdenum. The support 2 is inductively heated by the coil 9 and during the heating and the plating operations the support 2 is rotated being mounted on the top of the vertical shaft 11. The shaft 11 mounts and rotates the support 2 and also acts as a dispersion means for the vapor plating mixture by having a hollow center 12 communicating with the open center 13 of the support 2. A uniform heating of the discs 1 is obtained by the rotation of the support 2 in the field of the induction heating coil 9 and a uniform exposure of all portions of all of the discs 1 to the coating mixture of gas and vapor is obtained by the combination of the rotation of the support 2 and the provision of the centrally located mixture outlet 13 which provides for a uniform flow of the plating mixture over

all of the discs 1 spaced around the edge of the support 2.

In order to further insure uniform heating of the discs 1, induction heating coil 9 is mounted on an adjustable support plate 14 of a suitable heat resistant insulating material such as quartz. The relative position of the coil 9 with respect to the rotating support 2 is adjusted by changing the lengths of the threaded supports 15 which connect the coil support plate 14 to the rigidly mounted support member 16. It will be seen that a fine adjustment can be made of the length of each of the supports 15 by rotating the upper portion 17 on the threads 18 of the lower portion 19 so that any desired adjustment of the angular relationship between the coil 9 and the support 2 is made by suitable adjustment of the length of the supports 15. In order to prevent corrosion and contamination within the chamber, the heating coil 9 and the connecting leads 20 and 21 between the coil 9 and the coupling 10 are silver or silver coated. Both the leads 20 and 21 and the coil 9 are hollow tubes to permit a coolant to be passed through them during the plating operation.

The upper portion 22 of the shaft 11 for the support 2 is preferably made of a material which is heat resistant and corrosion resistant such as quartz. This upper portion 22 is mounted on a lower shaft 23 which also has a hollow center 24 communicating with the hollow center 12 of the upper portion 22 and which connects with the plating mixture inlet 7 through a rotating gland 25 which will be further described below. The rotatable shaft 11 is supported by a thrust bearing 26 in the top plate 27 of the base 6 and a rotating gland provided on the mixture conduit support member 28 within the base 6.

As described above, the shaft 11 and the inter-connected support 2 are continuously rotated during the vapor plating operation. The preferred embodiment of the drive for the shaft 11 includes the magnetic clutch 29 which permits the transmission of the drive torque from the variable speed drive motor 30 in the furnace base 31 through the solid bottom wall 32 of the base 6. The variable speed drive motor 30 is adjusted during the vapor plating operation to rotate support 2 at speeds of from about 5 to 30 r.p.m. depending upon the thickness of the coating being applied and other operating conditions.

In order to insure an absolutely air-tight chamber for the vapor plating operation and to prevent the entrance of any impurities which might enter the chamber through leakage in the mixture inlet system, the gland 25 which couples between the rotating shaft 11 and the conduit 28 is preferably mounted within the air-tight base 6 as best illustrated in FIG. 2. With the gland 25 located in this position, the initial evacuation of the chamber prior to the start of the vapor plating operation may be accomplished without the danger of leakage into the chamber through this gland as the gland itself is positioned within the chamber being evacuated. The closing of a suitable valve in the line to inlet 7 effectively isolates the entire gas and mixture inlet system from the surrounding atmosphere.

In addition, this positioning of the gland 25 within the base 6 minimizes any tendency of a gland 25 to leak during the vapor plating operation as the gland 25 is positioned within the base 6 adjacent the outlet 8. The pressure of the incoming mixture within the gland 25 will be greater than the pressure in the base 6 due to the continual withdrawal of gas from the chamber through exhaust outlet 8. Any leakage which might occur will tend to be outwardly of the gland 25 and there will be no entry of any gas through the gland 25 into the center 12 of the hollow support shaft 11.

A preferred embodiment of the rotating gland 25 is illustrated in detail in FIGS. 5 and 6. The gland 25 comprises a cavity 33 communicating with the inlet conduit 34 in support member 28 and surrounding a plurality of ports 35 coupling the hollow center 12 of the shaft 11 with the cavity 33. A pair of O-rings 36 are preferably used to seal the gland 25.

The O-rings 36 are retained in channels 37 (FIG. 5) formed by cooperating flared end 38 (FIG. 6) on the bearing hole 39 in the support 28 and flared ends 40 on the bearing holes 41 in a pair of sealing plates 42 and 43 mounted on the top and bottom of the support 28 as illustrated in FIGS. 5 and 6 so that the channels 37 have a generally triangular cross-section for the compressed O-rings 36. The sealing plates 42 and 43 are spring loaded by the compressed coil springs 44 on the coupling screws 45 which are threadedly connected to plate 43 and which pass through apertures 47 in plate 42.

The top plate 27 of the base 6 is cooled through the inlet 49 which connects a source of coolant to cooling channels 50 in the plate 27. The channels 50 connect to outlet 51.

The jar 4 is preferably air cooled by the tube 52 which sprays cooling jets of air onto the jar 4 through apertures 53. The vertical position of the tube 52 on the jar is adjusted to provide for cooling at the hottest portions of the jar 4.

Preferably, a cover 56 is positioned between the heating coil 9 and the support 2. This cover 56 which is formed of a heat resistant non-conducting material such as quartz reduces heat transfer from the disc 2 to the water cooled heating coil and prevents the deposition of silicon on the heating coil 9.

The top and bottom plates 27 and 32 of the base 6 as well as the base sidewall 54, the support 28 and the shaft 23 are preferably made of corrosion resistant metal such as stainless steel.

A typical operating cycle for the above described coating method and apparatus will now be described.

With the jar 4 removed from the base by releasing clamp 48, the silicon discs 1 which are to be coated are first carefully placed on the support 2. The jar 4 is now placed on the seal 5 on the base 6 and is clamped into position to seal the air-tight chamber. A vacuum is now drawn in the air-tight chamber surrounding the discs 1 of the order of about one micron. The chamber is next flushed with helium by passing it through the chamber between the inlet 7 and the outlet 8. A high frequency voltage source is now connected to the induction heating coil 9 which is preferably about a 450 kc. signal adjusted to provide power in the range of from 5 to 10 kw. in the chamber. The induction heating coil 9 now heats the molybdenum support 2 and the silicon discs 1 arranged around the edges of the support plate 2. The temperature of the discs 1 is observed by means of an optical pyrometer through a viewing surface 55 provided on the jar 4. During the heating, the support 2 is rotated at speeds of from 5 to 30 r.p.m. to insure a uniform heating of the several silicon discs 1 and pure hydrogen is passed through the chamber between inlet 7 and outlet 8. A continuous supply of coolant is passed through the coil 9 and the cooling channel 50 for the base and bearings during the operation of the induction heating coil 9. When the silicon discs 1 have reached a temperature of between 1250 and 1350 degrees C., the vapor plating is commenced by the admission of hydrogen gas containing silicon tetrachloride vapor through inlet 7. This mixture enters through the above described conduits to the center 12 of the rotating shaft 11 and it then flows outwardly and over the heated discs 1 on the rotating support 2 in a uniform pattern. When the mixture of hydrogen and silicon tetrachloride vapor contacts the heated surfaces of the discs 1, it reacts at the heated surface to deposit an adherent coating of silicon on each of the discs 1. In a typical silicon coating operation, the pressure in the chamber at the discs 1 is maintained at about 1 to 2 p.s.i. above atmospheric pressure and the spent gases flow downwardly through the jar 4 to the exhaust zone within the base 6 which is kept at about atmospheric pressure by the continuous evacuation of the spent gases through the exhaust outlet 8 to the atmosphere. This provides for a continuous flow of the mixture past the heated discs

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1. The thickness of the silicon coating on the discs is controlled by controlling the pressure and the flow rates of the incoming mixture as well as the proportions of hydrogen and silicon tetrachloride in the mixture and by continuing the flow of mixture for a predetermined time. When this time period has elapsed, the supply of the mixture and the current to the heating coil 9 is cut-off and the chamber is opened by the removal of the jar to provide access to the coated discs after a suitable cooling period.

It will be seen that an improved method and apparatus for forming a vapor plating or coating on articles has been disclosed which provides for coatings of a predetermined thickness and a highly uniform thickness over the entire coated surface by improved control of the article heating and the flow of the coating gases and vapors. In addition, a method and an apparatus have been disclosed which provide for a vapor coating of extremely high purity and one in which the above improved results are obtained by the use of equipment which is relatively easy to operate and which is compact in form and safe in operation.

As various changes may be made in the form, construction and arrangement of the parts herein without departing from the spirit and scope of the invention and without sacrificing any of its advantages, it is to be understood that all matter herein is to be interpreted as illustrative and not in a limiting sense.

Having thus described my invention, I claim:

1. Apparatus for vapor plating a plurality of articles comprising the combination of a sealed chamber, a hollow generally vertically mounted shaft, an electrically conductive article support for carrying a plurality of articles in a generally circular pattern and mounted on said shaft, an induction heating coil concentric with said shaft and adjacent to said support, means for rotating said shaft, the hollow portion of said shaft communicating with the surface of said support centrally of the path of movement of the articles thereon for providing a vapor outlet, and a vapor inlet communicating with the hollow portion of said hollow shaft.

2. Apparatus for vapor plating comprising the combination of a sealed chamber, an induction heating coil in said chamber, a metallic article support mounted on a rotatable shaft adjacent said coil, said shaft being hollow, the hollow portion of said shaft communicating with the

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surface of said support to provide a vapor outlet, and a coupling gland engaging said shaft within said sealed chamber for coupling the hollow portion of said shaft with a source of vapor.

3. Apparatus for vapor plating comprising the combination of a sealed chamber, an induction heating coil in said chamber, a metallic article support having a plurality of equally spaced article positioning means thereon and mounted on a rotatable shaft adjacent said coil, said shaft being hollow, the hollow portion of said shaft communicating with the surface of said support at a position substantially equidistant from said positioning means to provide a vapor outlet, a coupling gland engaging said shaft within said sealed chamber for coupling the hollow portion of said shaft with a source of vapor, and a non-conducting heat resistant member intermediate said coil and said support.

4. The apparatus as claimed in claim 3 in which said support comprises molybdenum.

5. The apparatus as claimed in claim 3 in which said chamber has an exhaust outlet adjacent said gland.

6. The apparatus as claimed in claim 2 which includes means for adjusting the spacing between said article support and said heating coil.

7. The apparatus as claimed in claim 3 which includes means for adjusting the spacing between said article support and said heating coil.

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Disclaimer

3,233,578.—*Emil Robert Capita*, North Bergen, N.J. APPARATUS FOR VAPOR PLATING. Patent dated Feb. 8, 1966. Disclaimer filed Dec. 4, 1968, by the assignee, *Western Electric Company, Incorporated*. Hereby enters this disclaimer to claims 1 and 2 of said patent.
[*Official Gazette June 17, 1969.*]