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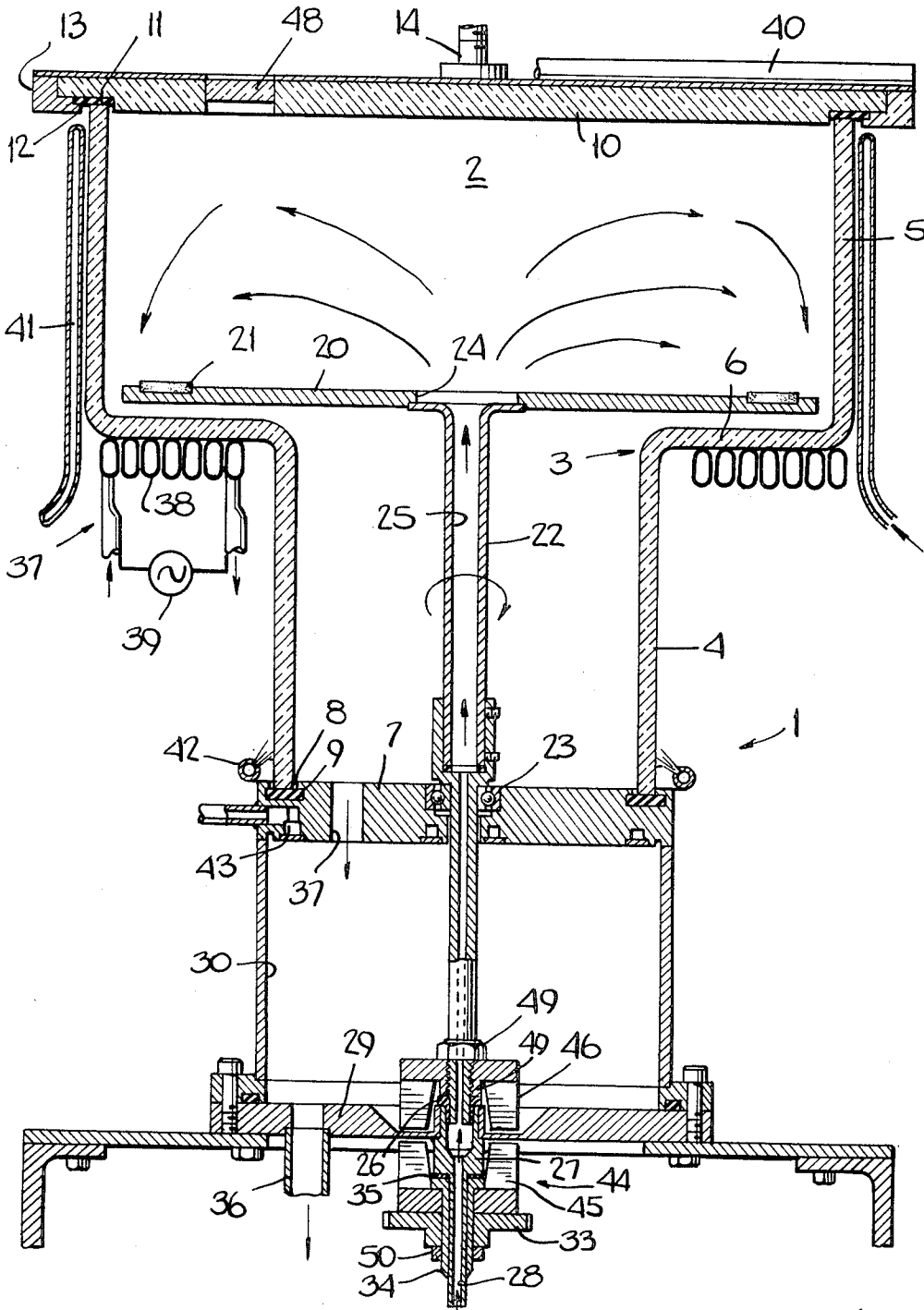
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VAPOR PLATING APPARATUS INCLUDING ROTATABLE SUBSTRATE SUPPORT

Filed Aug. 25, 1966

2 Sheets-Sheet 1



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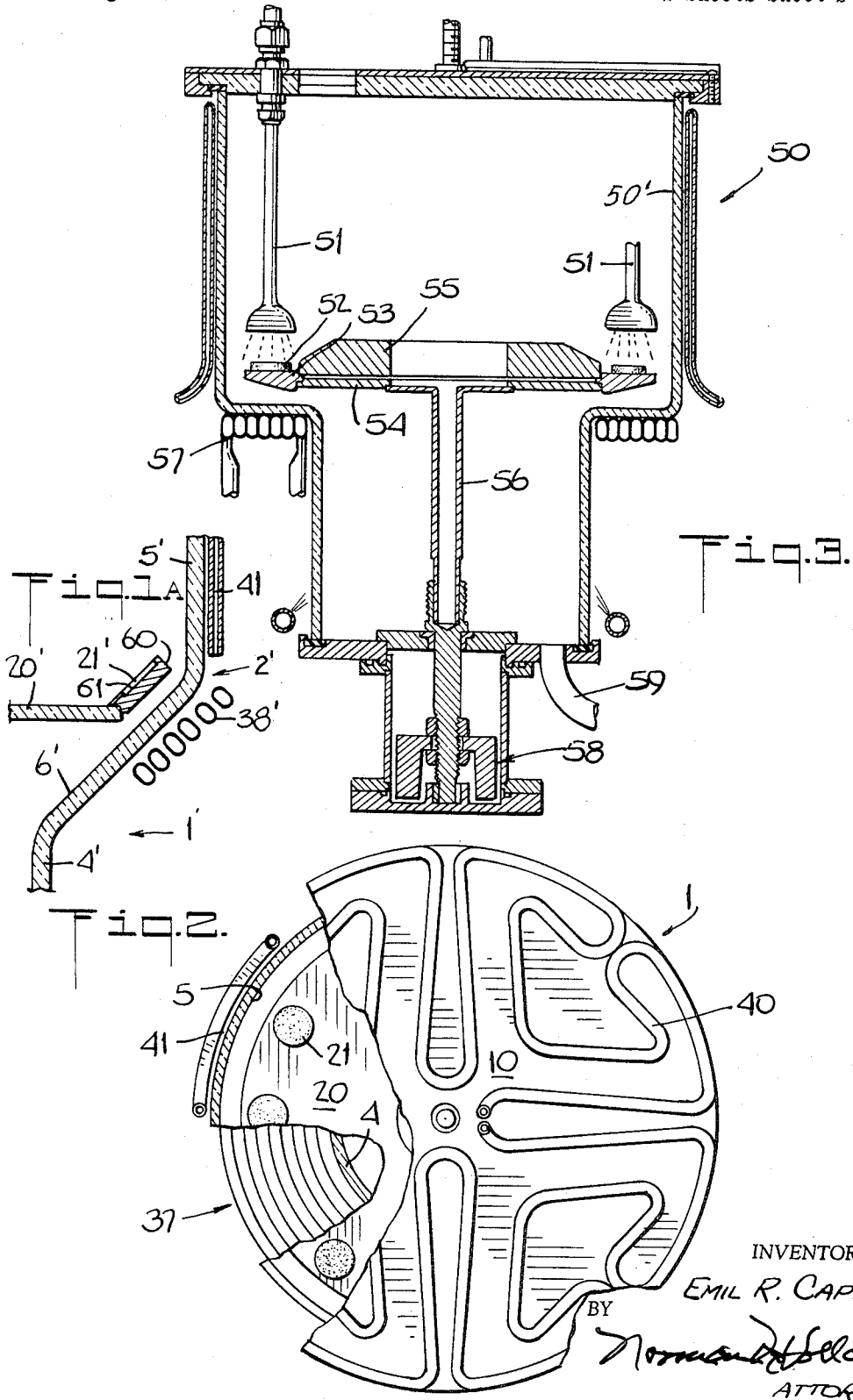
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VAPOR PLATING APPARATUS INCLUDING ROTATABLE SUBSTRATE SUPPORT

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3 Claims. (Cl. 118—49.5)

The present invention relates to a vapor plating means and more particularly to an improved vapor coating furnace having an induction heating system.

Vapor plating furnaces of this general type are known as for example the furnace illustrated in my United States Patent No. 3,233,578, dated Feb. 8, 1966.

These prior furnaces include induction heating means for vapor coating operations and provide an effective heating and coating arrangement. Certain coating operations, however, require an even higher degree of purity or an almost absolutely pure and totally uncontaminated furnace atmosphere and the improved furnace of the present invention provides such an atmosphere.

As will be more fully described below, this is obtained by a physical isolation of the induction heating coils from the atmosphere surrounding the articles being coated and in particular by the location of the induction heating coils for heating the articles outside of the vapor chamber in which the coating operation is carried out.

The basic coating action employed in the furnace comprises the placement of the articles on an electrically conductive support or susceptor. The susceptor is inductively heated as it moves the articles being coated through an atmosphere of a volatile compound where the heated article surfaces reduce or decompose the compound resulting in the deposition of the desired coating on the article surfaces.

A typical vapor deposition operation for which the furnace is useful is a hydrogen-reduction process where hydrogen is passed over a heated liquid metal halide vapor. This vapor when admitted within the evacuated furnace chamber reacts at the heated surface and deposits an adherent coating of the non-volatile reaction product.

An example of such a deposition process is in applying silicon coatings to silicon discs as used in the manufacture of transistors.

Accordingly, an object of the present invention is to provide improvements in vapor plating.

Another object of the present invention is to provide an improved vapor plating means providing for increased purity of the applied coatings.

Another object of the present invention is to provide an improved vapor plating furnace with an induction heating means positioning at least partially outside the coating chamber.

Another object of the present invention is to provide an improved vapor coating furnace with an improved coating chamber.

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 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 vertical sectional view of an improved vapor coating furnace in accordance with the present invention;

FIG. 1a is a fragmentary vertical sectional view of another embodiment of the furnace of FIG. 1;

FIG. 2 is a top plan view of the furnace of FIG. 1, partially cut away; and

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FIG. 3 is a vertical sectional view of another embodiment of the vapor coating furnace in accordance with the present invention.

The invention will now be described in connection with the manufacture of silicon coated slices such as are used in the manufacture of P-N type transistor elements where in the slices comprise the N-type and a silicon coating on the slice comprises the P-type.

While described for such a coating operation, it is clear that the furnace is applicable to other coating operations where a vapor is decomposed by heat at an article surface.

As seen in FIG. 1, the furnace 1 comprises an air tight heat resistant chamber 2 formed principally of a heat resistant material such as quartz. The preferred enclosure illustrated has its side wall 3 formed of quartz with its lower side wall portion 4 and a larger upper side wall portion 5 interconnected by a generally horizontal center portion 6. The side walls 3 are mounted on a base 7 including an annular sealing ring 8 preferably contained in a suitable mounting channel 9 for providing an air tight and detachable connection between the side walls 3 and the base 7.

The top of the furnace chamber 2 is sealed by a quartz cover 10 also including an annular sealing gasket 11 detachably mounted in a groove 12 and held therein by a ring-like clamping member 13. In order to make the interior of the furnace chamber 2 easily accessible for loading and unloading and for cleaning, the cover 10 and the side walls 3 are detachably connected together and to the base 7 by being held together and pressed downwardly by a central threaded clamping member 14.

The hollow air-tight chamber 2 contains an annular susceptor 20 which supports the articles or slices 21 being coated and which is detachably positioned on a hollow support shaft 22 mounted in a suitable bearing 23 in the base 7 and on a thrust bearing 26 positioned on a vapor inlet 27 so that the slices 21 are moved in a circular path within the furnace chamber 2.

In the preferred embodiment illustrated in FIG. 1, the vapor which is to be decomposed during the coating operation is fed into the hollow chamber 2 through the open center 24 in the susceptor 20 from the hollow center 25 of the support shaft 22. The vapor is fed into the hollow center 25 of shaft 22 through a conduit 28 in vapor inlet 27. The vapor inlet 27 is fixedly attached to the bottom 29 of the exhaust chamber 30.

An initial vacuum is created within the chamber 2 and the subsequent flow of the vapor is maintained over the slices 21 by connecting an outlet 6 to a suitable pump (not shown). The exhaust chamber 30 communicates with the chamber 2 through a port 37. Since a continuous outward flow is maintained through the outlet 36 during operation any leakage of vapor that may occur at the thrust bearing 26 does not reach the atmosphere since this leakage is also drawn outwardly through the outlet 36.

An induction heating coil 37 comprising the tubular members 38 formed into a spiral is mounted adjacent to the central portion 6 of the furnace chamber 2 side walls 3. The opposite ends of the coil 37 are connected to an alternating electrical power source schematically indicated at 39. Current from this source passes through the coil 37 inducing heating currents in the susceptor 20 which is formed of molybdenum or silicized graphite to raise the slices 21 mounted on the susceptor 20 to the necessary coating temperature at which the vapors will be decomposed. In order to provide an efficient and uniform heating of the slices, a preferred arrangement of the coil 37 is a flat spiral positioned relatively close to the susceptor 20. This preferred mounting is facilitated

by the generally horizontal intermediate portion 6 of the chamber side walls 3. The induction heating coil 37 is adjustably positioned immediately below this portion 6 and for maximum heat transfer the coil 37 may rest in contact with this base.

The coil 37 is kept at a relatively low temperature and a simultaneous cooling of the horizontal intermediate section of the chamber walls is effected by passing a coolant through the hollow members 38 of the heating coil 37.

Cooling conduits 40 are also mounted in engagement with the cover 10 and a second elongated cooling conduit 41 is mounted adjacent the upper portion 5 of the chamber side walls 3. A coolant is continuously passed through these cooling conduits 40 and 41. A preferred means for cooling the lower portion 4 of the chamber side walls comprises a cooling air spray supplied from suitable outlets in a conduit 42 positioned at the lower edge of the side walls 4. In the preferred embodiment, the base 7 is also cooled by the provision of an internal cooling conduit 43 through which a continual supply of coolant is passed.

An air-tight drive coupling is illustrated at 44 for transmitting the susceptor rotating torque to the shaft 22 by means of the spaced magnetically coupled magnets 45 and 46. The lower drive magnet 45 and a drive gear 33 are coupled together on a gear bushing 34 by nut 50. The magnet 45 and gear 33 are rotatably supported on the vapor inlet 27 against a thrust bearing 35. A suitable variable speed drive coupled to gear 33 rotates the lower magnet 45 which transfers the rotating torque through the bottom 29 of the exhaust chamber 30 to the upper drive magnet 46 which is connected to the lower end of the drive shaft 22 between coupling nuts 45.

The embodiment illustrated in FIG. 3 distributes the vapor from one or more stationary nozzles 51 positioned above a portion of the path of a rotating susceptor 53 formed of a current conductor such as molybdenum or silicized graphite. In this embodiment, the slices 52 pass through a relatively heavy vapor concentration during a relatively short portion of their circular path. This embodiment is useful in certain coating processes as, for example, where extremely thin coatings are being applied and where precise thickness control is being maintained for such thin coatings. The same vapor may be applied through all the nozzles 51 or different vapors may be applied through separate nozzles for coating known as polycrystal deposition. The furnace 50 includes a quartz chamber 50' with side walls generally similar to that already described above for the furnace, as well as heating coils 57 positioned outwardly of the side walls 50' and beneath the moving slices 52 as illustrated. A rotatable vertical shaft 56 is provided to support the susceptor 53 on an annual support plate 54. A hold-down plate 55 is illustrated for detachably supporting the susceptor 53 in its coating position. A magnetic drive for the shaft 56 is illustrated at 58 and an exhaust port for the furnace chamber is shown at 59.

FIG. 1A illustrates another embodiment in which the furnace 1' chamber 2' is modified by having an inclined or flared connecting portion 6' between the vertical lower section 4' and upper section 5'. In this embodiment, an inclined or generally frusto-conical molybdenum or silicized graphite outer susceptor ring 60 is provided on the inner support 20' having the slices 21' mounted in recesses 61 which help resist the centrifugal forces on the rotated slices 21'. The coil 38' also has a flared or generally frusto-conical form corresponding to the incline of the wall portion 6' and the susceptor ring 60.

A typical operation for coating silicon slices will now be described. With the cover 10 removed from the base 7 by releasing clamp 14, the silicon slices 21 which are to be coated are first carefully placed on a clean susceptor 21. The chamber 3 is now closed and a vacuum is now

drawn in the air-tight chamber 3 surrounding the slices 21 of the order of about one micron. The chamber is next flushed with helium by passing it through the chamber 3 between the inlet 32 and the outlet 36. A high frequency voltage source is now connected to the induction heating coil 37 which is preferably a source adjustable in the range of about 10 kc. to 450 kc. and capable of providing power in the range required which conveniently may be from 5 to 10 kw. in the chamber. The induction heating coil 37 now heats the molybdenum susceptor 20 and the silicon slices 21 arranged around the edges thereof. The temperature of the slices 21 is observed by means of a optical pyrometer through a viewing surface 48.

During the initial heating, the susceptor 20 is rotated at speeds of from 5 to 30 r.p.m. or higher to insure a uniform heating of the several silicon slices 21 and pure hydrogen is passed through the chamber between inlet 32 and outlet 36. When the silicon slices 21 have reached a temperature of between 1190 and 1450 degrees C. the vapor plating is commenced by the admission of hydrogen gas containing silicon tetrachloride vapor through inlet 32. This mixture enters through the above described conduits to the center 25 of the rotating shaft 22 and it then flows outwardly and over the heated slices 21 on the rotating susceptor 20 in a uniform pattern. When the mixture of hydrogen and silicon tetrachloride vapor contacts the heated surfaces of the slices 21, it reacts at the heated surface to deposit an adherent coating of silicon on each of the slices 21. In a typical silicon coating operation, the pressure in the chamber at the slices 21 is maintained at about 1 to 2 p.s.i. above atmospheric pressure and the spent gases flow downwardly through to the exhaust zone within the base 7 which is kept at about atmospheric pressure by the continuous evacuation of the spent gases through the exhaust outlet 36 to the atmosphere. This provides for a continuous flow of the vapor mixture past the heated slices 21. The thickness of the silicon coating on the slices 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 37 are stopped and the chamber is opened by the removal of the cover 10 to provide access to the coated discs 21 after a suitable cooling period.

The embodiments of FIGS. 1A and 3 operate in a similar manner except for the use of one or more nozzles 51 to supply the vapor in the embodiment of FIG. 3.

It will be seen that an improved vapor coating furnace has been provided for applying coatings of extremely high purity by means of an induction heating process. The vapor decomposition heating means is capable of applying high purity coatings while being also readily adaptable for a variety of operating conditions including various decomposable vapors and for use with a variety of articles. The article temperatures and rates of movement and the vapor flow are conveniently controlled over relatively wide ranges as may be necessary or most convenient.

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.

I claim:

1. Apparatus for vapor plating a plurality of articles comprising the combination of a sealed chamber, a rotatably mounted support having a generally vertical axis, an electrically conductive article susceptor mounted on said support for carrying a plurality of articles in a generally circular path, said chamber having a lower portion connected to a larger upper portion by a frusto-conical portion, said susceptor having an inwardly and upwardly

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facing frusto-conical article supporting portion including article engaging recesses, whereby said articles are supported in a manner to resist the effects of centrifugal forces developed upon rotation of said susceptor, said frusto-conical portion of the susceptor being positioned adjacent to and generally parallel to the frusto-conical portion of said chamber, an induction heating coil having a plurality of turns arranged in frusto-conical form and positioned outside of said chamber and adjacent to and generally parallel to said frusto-conical portion of said chamber, means for rotating said support, and a vapor outlet in said chamber positioned for directing vapor over articles on said susceptor.

2. The apparatus as claimed in claim 1 in which said chamber has a removable cover on said upper portion for facilitating removal of the susceptor.

3. The apparatus as claimed in claim 1 in which the

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turns of the induction heating coil are hollow for liquid cooling.

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