

Aug. 13, 1968

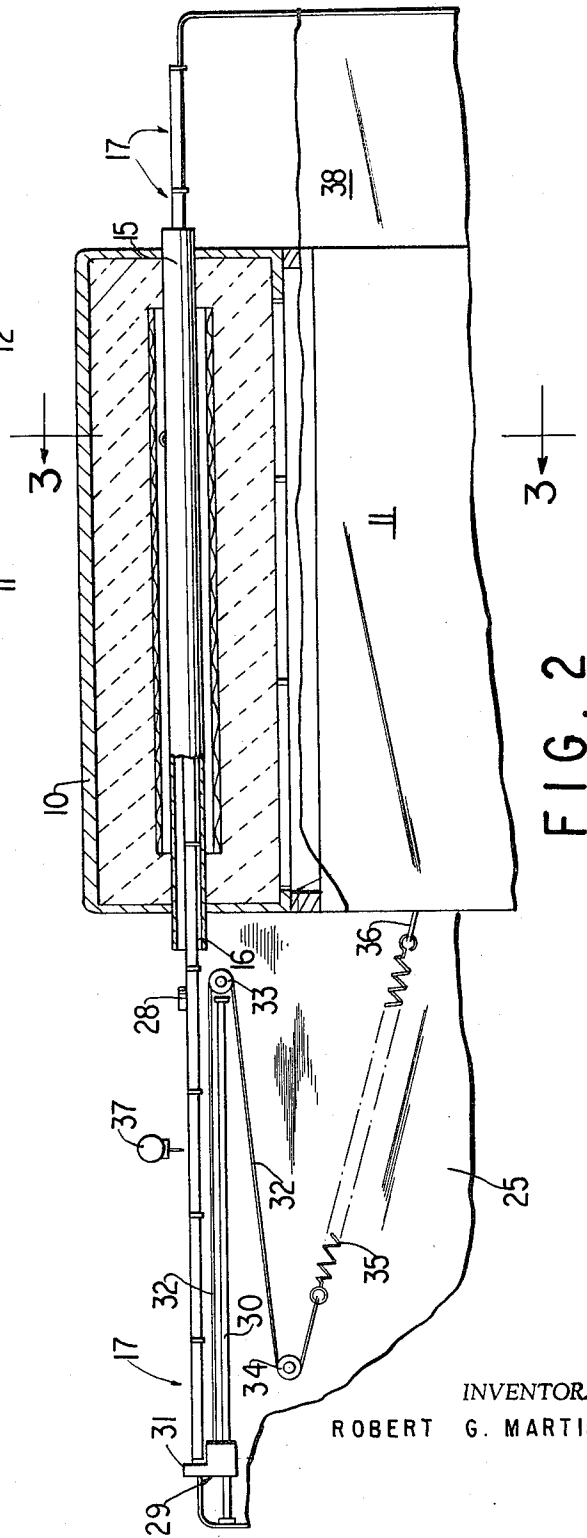
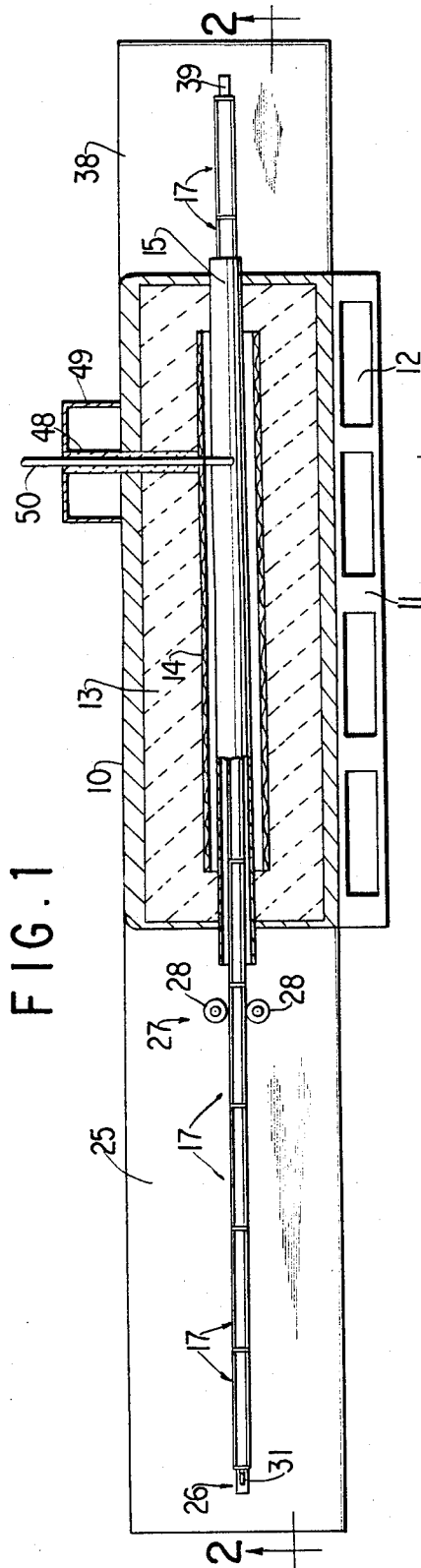
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3,396,955

DIFFUSION FURNACE WITH TRANSPORT MEANS

Filed Oct. 4, 1965

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

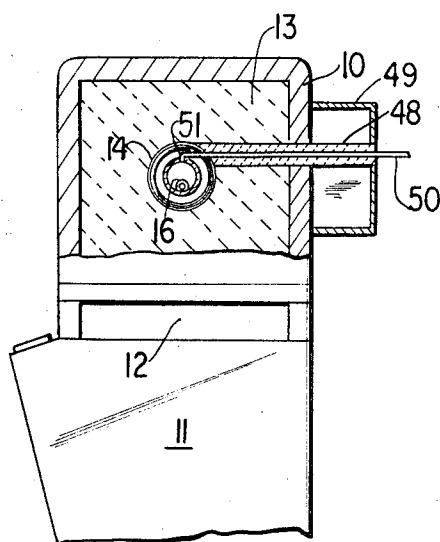


FIG. 3

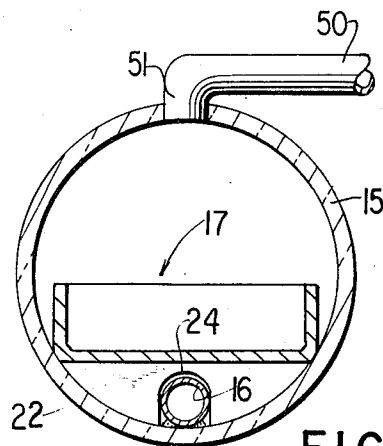


FIG. 4

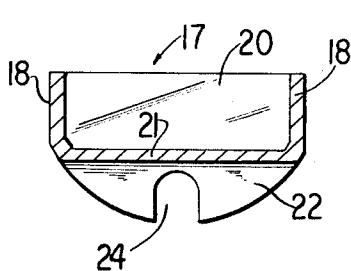


FIG. 6

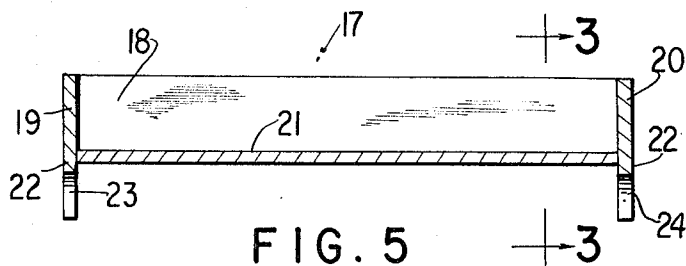


FIG. 5

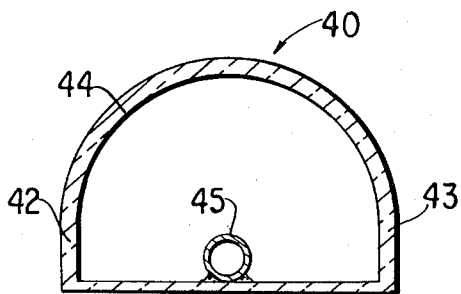


FIG. 7

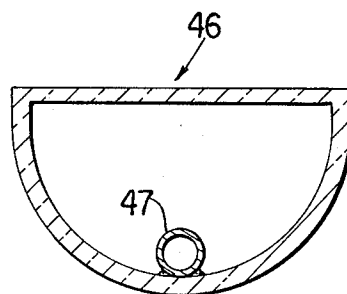


FIG. 8

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DIFFUSION FURNACE WITH TRANSPORT MEANS

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Filed Oct. 4, 1965, Ser. No. 492,794

5 Claims. (Cl. 266—1)

ABSTRACT OF THE DISCLOSURE

A diffusion furnace consisting of a refractory housing with a hollow heating element embedded therein and a tubular heating element arranged concentrically within the heating element having track means therein. Boat means conforming in cross section to that of the heating chamber are pushed in abutting relationship along the track means whereby gases introduced into the heating chamber are caused to diffuse into the material being transported therethrough in the boat means.

This invention relates to furnaces and particularly to an improved diffusion furnace for use in the manufacture of semiconductors and the like.

At present, transistors and semiconductor devices are manufactured in heat-treating furnaces of a very specialized nature. They are usually the small-batch type tube furnaces because of the extremely small size of the semiconductors for transistor use. These prior known furnaces usually operate in a temperature range up to about 1300° C., and materials are diffused into silicon in a time-temperature function, and fluctuations in this time-temperature relationship result in products of different quality. In order to make time the only variable in this process, the silicon wafers have been exposed in quartz containers for exactly the same temperature. This is the reason that batch-type diffusion furnaces require extremely sophisticated temperature control systems that ensure constant temperatures at 1300° C. plus or minus a half a degree centigrade.

The process of producing semiconductors for transistors requires the diffusion into the silicon of certain materials either in solid, liquid or gaseous form. When the source of material to be diffused into the silicon is gaseous in form, it is necessary to provide a source furnace where the solid source is evaporated and the vapor is carried by an atmosphere into the diffusion main chamber.

Prior known heating cycles in the manufacture of semiconductors were relatively long, for example, forty-eight hours. In such long cycles, inaccuracies in timekeeping were not too important. Recently, however, materials have been found requiring shorter and shorter cycle times, some of which are as low as from 10 to 30 minutes. With such short time cycles, it becomes obvious that timing mistakes have a greater influence on the quality produced.

Recently developed semiconductors, for example, are multilayer in form and are produced by a series of steps that may involve as many as ten to twenty diffusion operations, the cycle time of which is usually of a short nature, for instance between 8 and 30 minutes.

The principal object of the present invention is to produce a continuous diffusion furnace having the capability of meeting the demands of industry including multiple cycles of short duration.

Another object of the invention is to provide such a furnace including means for conveying boat-like containers continuously therethrough.

Another object of the invention is to provide such a furnace in which guide means for the boats may be lo-

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cated within the heating chamber and which may incorporate temperature responsive means.

Still another object of the invention is to provide such a furnace having the capability of effecting gaseous diffusion of the material contained within the boats as they pass through the heating chamber.

A further object of the invention is to provide such a furnace in which the cross sectional shape of the heating chamber and that of the work-carrying boat are compatible so as to facilitate continuous movement of the boats through the heating chamber.

A still further object of the invention is to provide such a furnace in which driving means is provided for continuously feeding succeeding boats in abutting relation through the heating chamber of said furnace.

Still another object of the invention is to provide such a furnace in which a continuously acting means is employed to move the loaded boats into engagement with the continuous feeding means.

In one aspect of the invention, a continuous diffusion furnace may comprise a housing having a tubular heating element embedded within refractory material, which latter may entirely fill the housing.

In another aspect of the invention, an elongated, tube-like member may extend from the outside at one end of the housing, through the tubular heating element and out the opposite side of the housing. The tubular member preferably is made of quartz, but may be made of refractory material, platinum or other suitable metal.

In a further aspect of the invention, an inlet to the interior of the tubular member within the confines of the housing may be provided for admitting material in gaseous form to be diffused into the material being transported through the tubular member.

In a still further aspect of the invention, the tubular member may be provided with internal track means, preferably made of the same material as the tubular member, for guiding the boat-like containers as they are pushed by a continuous feeding means through said tubular member.

In a further aspect of the invention, the tubular member may be circular with a hollow, circular track element at its lowest point extending longitudinally therethrough, or it may be semicircular, either upright or inverted, with a hollow, tubular element extending longitudinally along its base throughout its entire length for guiding boats containing the material to be treated.

In a still further aspect of the invention, boat-like containers may have a cross sectional configuration compatible with that of the tubular member so as to prevent transverse tipping of the boat while it is being pushed through the tubular member. These boats may include a notch in their bases adapted to receive the tubular track means in the base of the tubular member.

In another aspect of the invention, there may be provided means for continuously feeding the boats into the tubular member, and such feeding means may be located at the entrance end to the furnace.

In another aspect of this invention, pusher means may be provided at the beginning of another track means that feeds the boats in abutting relation to the continuously operating feeding means, and there may be provided warning means in combination with the pusher means so as to alert the operator when the pusher conveyor means is to be replenished with additional boats.

In a further aspect of the invention, there may be provided a receiving table at the exit end of the furnace, and it may include a portion of track means adapted to guide the boats as they leave the furnace for subsequent movement to another location.

The above, other objects and novel features of the invention will become apparent from the following speci-

fication and accompanying drawings which are merely exemplary.

In the drawings:

FIG. 1 is a top plan view partly in section of a furnace to which the principles of the present invention have been applied;

FIG. 2 is a sectional elevational view taken substantially along line 2—2 of FIG. 1;

FIG. 3 is a sectional elevational view taken substantially along line 3—3 of FIG. 2;

FIG. 4 is an enlarged view of a portion of the section shown in FIG. 3;

FIG. 5 is a longitudinal sectional elevational view of a boat forming an element of the present invention;

FIG. 6 is a sectional view taken substantially along line 6—6 of FIG. 5; and

FIGS. 7 and 8 show modified cross sectional forms of the tubular heating chamber shown in FIG. 4.

Referring to the drawings, and particularly to FIGS. 1 and 2, the principles of the invention are shown as applied to a furnace including a housing 10 adapted to be supported by a stand 11 or any other suitable means which may include ventilating pockets 12 adjacent the supporting surface thereof. Housing 10 may be filled with suitable refractory material 13 in which a heating element 14 may be embedded, and which in the embodiment disclosed is shown as a tubular heating element. A tubular heating chamber 15 may be concentrically located relative to heating element 14 with its outer walls spaced from the inner wall of the element 14. The tubular chamber is preferably made of quartz, although refractory materials and other metals such as platinum may be employed under certain circumstances. In the embodiments disclosed in FIGS. 1 to 4, the tubular chamber 15 is shown as circular and includes a track element 16 (FIG. 4) that is shown as a circular tubular element which preferably also is made of quartz, and in any instance is made of the same material as chamber 15.

Referring to FIGS. 4 to 6, boat-like containers 17 may comprise channel-shaped elements 18 that are closed at both ends by walls 19 and 20. The walls 19 and 20 may extend below the bottom 21 of the containers, and this lower portion of the walls 19, 20 may include arcuate portions 22 that conform with the curvature of the inner surface of the tubular chamber 15. Arcuate portions 22 may be provided with aligned notches 23, 24 therein adapted to receive the tubular track 16. The construction is such that with a boat 17 within the chamber 15 and the notches 23, 24 embracing the track 16, the container or boat can be pushed through chamber 15 without danger of lateral tipping as it passes therethrough.

Referring again to FIGS. 1 and 2, a support 25 may be located at the end of stand 11 adjacent the entrance to the housing 10. The support 25 may include track means 26 that is aligned with track means 16 within chamber 15. One or more pairs of driving rolls 27 may be located adjacent the entrance end of chamber 15. Rolls 27 may comprise plastic rolls 28 which preferably may be made of the plastic known in the trade as "Teflon" or they may be coated with "Teflon" when quartz boats 17 are employed. Rolls 28 may be arranged to rotate about vertical, spaced axes which may be urged toward each other under a uniform force so as to provide a substantially uniform frictional driving force tending to feed each boat 17 successively from the support 25 into the chamber 15 along the tracks 26 and 16.

In order continuously to supply boats 17 to the feeding rollers 28, a pusher element 29 may be mounted for reciprocable movement along a rod 30 that is mounted on the support 25 parallel with the track means 26. Element 29 is provided with a finger 31 adapted to lie over track 26 in position to contact the end of a boat 17.

The element 29 may also be connected to a flexible cord 32 that passes over an idler pulley 33 mounted on support 25. The cord 32 may then extend around another

idler pulley 34 on support 25 and be connected to a spring 35, or its equivalent, that is anchored at 36 to the stand 11. In operation, a plurality of boats 17 are mounted along the track 26 on support 25 with the pusher finger 31 in contact with the trailing end of the boat 17 farthest from the housing 10. The spring 35 continually urges the finger 31 rightwardly (FIGS. 1 and 2), thereby pushing the boats 17 in between the feeding rolls 28 under a constant force, whereupon the rollers 28 frictionally feed the boats successively and in abutting relation with respect to each other through chamber 15 along the track 16. When the pusher finger 31 arrives at a predetermined point in its path of travel, it is adapted to actuate an alarm 37, warning the operator that additional boats 17 are required to be loaded on the support 25, whereupon the operator will retract the pusher finger 31 and insert additional boats 17 on track 26.

Table means 38 may be provided at the exit end of chamber 15 and it may include track means 39 in line with track means 16 within chamber 15. As the boats 17 move out of the tube 15, they are received by the table 38 from whence they are transported to another location for cooling.

Referring to FIG. 7, a tubular chamber 40 is shown as having a cross sectional construction including a flat face portion 41 and parallel walls 42, 43 that are joined by an arcuate section 44. A tubular track element 45 may be fixed to the center of the flat portion 41 of the chamber 40 and may extend throughout its entire longitudinal length.

Referring to FIG. 8, a tubular chamber 46 is shown which is substantially the same as chamber 40 except that it is in an inverted position. In the embodiment shown in FIG. 8, the track member 47 is fixed to the center of the arcuate portion of the chamber and extends longitudinally throughout chamber 46.

It is evident that a heating chamber such as that shown in FIG. 7 would require a boat construction having a non-arcuate base portion, whereas the species shown in FIG. 8 would accept the boat construction shown in FIGS. 5 and 6.

Referring again to FIGS. 1 and 3, a tube of refractory material 48 may extend from the heating element 14 through the refractory material 13 to the exterior of the housing 10. Guard means 49 may be provided for surrounding the refractory tubular member 48 to prevent its being damaged. A line 50 may lead from the exterior of housing 10 through the refractory tubular member 48, through the heating element 14, being insulated therefrom, and extending into the interior of the chamber 15 by the elbow means 51. The line 50 may be connected to a furnace (not shown) in which solid diffusion material may be converted into gaseous form and transferred from this furnace through line 50 into the interior of the heating chamber 15 for supplying the source material that is to be diffused into the silicon being conveyed through the chamber 15 within the boats 17.

In order to control the temperature within the chamber 15, thermocouple means may be located within the tubular track means 16 in chamber 15. The thermocouple means may be employed to actuate control means (not shown) for varying the current supplied to the heating element 14 within the furnace.

Although the various features of the improved diffusion furnace have been shown and described in detail to fully disclose several embodiments of the invention, it will be evident that changes may be made in such details and certain features may be used without others without departing from the principles of the invention.

What is claimed is:

1. In a diffusion furnace, a housing; refractory material within said housing; a hollow heating element embedded within said refractory material; a hollow heating chamber arranged concentrically with respect to, and

spaced inwardly from the inner wall of said heating element; track means within said heating chamber; channel-shaped boat means having a cross sectional construction that at least partially conforms to the cross section of said heating chamber and including apertured means depending from said boat means for receiving said track means, said boat means having silicon materials therein; and means for continuously feeding a plurality of said boat means into the entrance end of said heating chamber, and conduit means for introducing diffusion gases into said heating chamber and for diffusion into said silicon materials in said boat means.

2. In a diffusion furnace, a housing; refractory material within said housing; a hollow heating element embedded within said refractory material; a hollow heating chamber arranged concentrically with respect to, and spaced inwardly from the inner wall of said heating element; track means within said heating chamber; boat means having a cross sectional construction that at least partially conforms to the cross section of said heating chamber and including apertured means depending from said boat means for receiving said track means; a support adjacent the entrance end of said heating chamber; track means on said support in line with the track means within said heating chamber; a plurality of aligned abutting boat means on the track means on said support, said boat means having silicon materials therein; and a plurality of spaced rolls adapted to rotate about vertical axes between which said boat means are adapted to pass for continuously feeding said boat means into the entrance end of said chamber, and conduit means for introducing diffusion gases into said heating chamber and for diffusion into said silicon materials in said boat means.

3. In a diffusion furnace, a housing; refractory material within said housing; a hollow heating element embedded within said refractory material; a hollow heating chamber arranged concentrically with respect to, and spaced inwardly from the inner wall of said heating element; track means within said heating chamber; channel-shaped boat means having a cross sectional construction that at least partially conforms to the cross section of said heating chamber and including apertured means depending from said boat means for receiving said track means; a support adjacent the entrance end of said heating chamber; track means on said support in line with the track means within said heating chamber; a plurality of aligned abutting boat means slidably mounted on the track means on said support; a plurality of spaced rolls adapted to rotate about vertical axes between which said boat means are adapted to pass for continuously feeding said boat means into the entrance end of said chamber; and pusher means adapted to act on said aligned boat means on said support, and flexible means engageable

with said pusher means for urging them into engagement with said feeding means.

4. In a diffusion furnace, a housing; refractory material within said housing; a hollow heating element embedded within said refractory material; a hollow cylindrical heating chamber arranged concentrically with respect to, and spaced inwardly from the inner wall of said heating element; elongated track means within and secured to said heating chamber; channel-shaped boat means having a cross sectional construction that at least partially conforms to the curved cross section of said heating chamber and including spaced apertured means depending from said boat means for receiving said track means; a support adjacent the entrance end of said heating chamber; track means on said support in line with the track means within said heating chamber; a plurality of aligned channel-shaped abutting boat means on the track means on said support; a plurality of spaced rolls adapted to rotate about vertical axes between which said boat means are adapted to pass for continuously feeding said boat means into the entrance end of said chamber; pusher means adapted to act on said aligned boat means on said support, and flexible means engageable with said pusher means for urging them into engagement with said feeding means; and alarm means responsive to said pusher means for indicating when additional boat means are to be mounted on said support ahead of said pusher means.

5. In a diffusion furnace, a housing; refractory material within said housing; a hollow heating element embedded within said refractory material; a hollow heating chamber of generally semicircular cross section arranged concentrically with respect to, and spaced inwardly from the inner wall of said heating element; elongated tubular track means within and secured to the bottom of said heating chamber; channel-shaped boat means having a cross sectional construction that at least partially conforms to the cross section of said heating chamber and including spaced apertured means depending from said boat means for receiving said track means; and means for admitting a gaseous medium into the interior of said heating chamber intermediate its ends.

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