

[54] CONTINUOUS DEPOSITION SYSTEM

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[58] Field of Search 118/48-49.5, 620;
117/107.1, 107.2, 106; 219/388, 275, 347;
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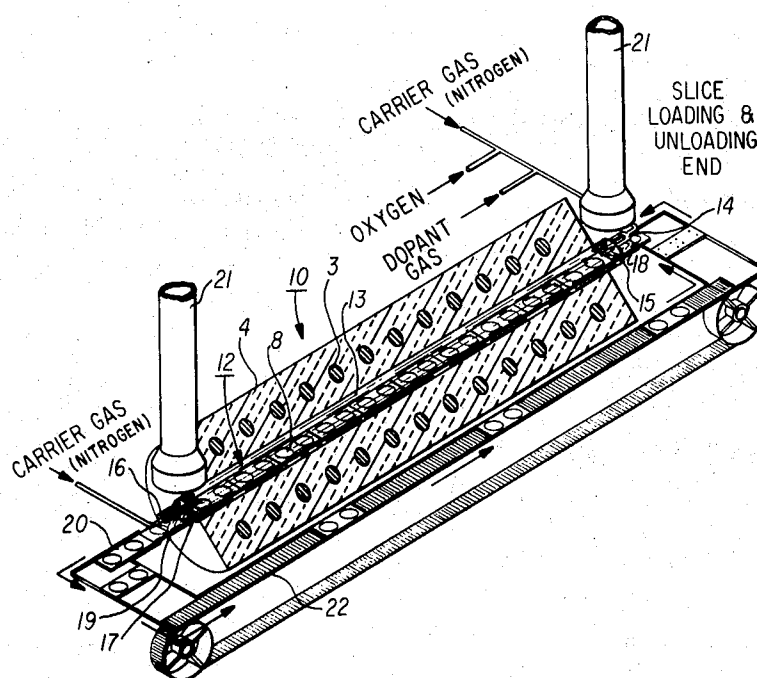
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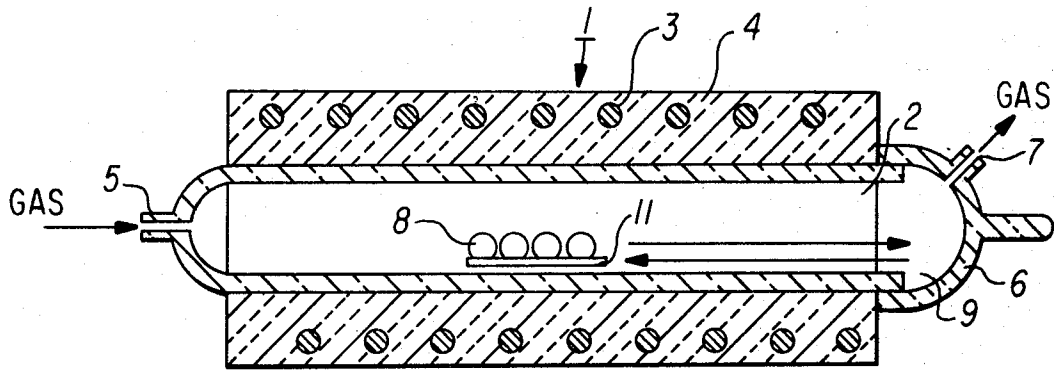
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ABSTRACT

Means pass a substrate through a hemi tubular vapor deposition chamber disposed within a furnace means. A plurality of gas feed means pass through each end wall of, and extend substantially into, the chamber whereby to preheat the gases. Effluent gases pass out through the substrate entry and exit means.

2 Claims, 5 Drawing Figures





PRIOR ART

Fig. 1

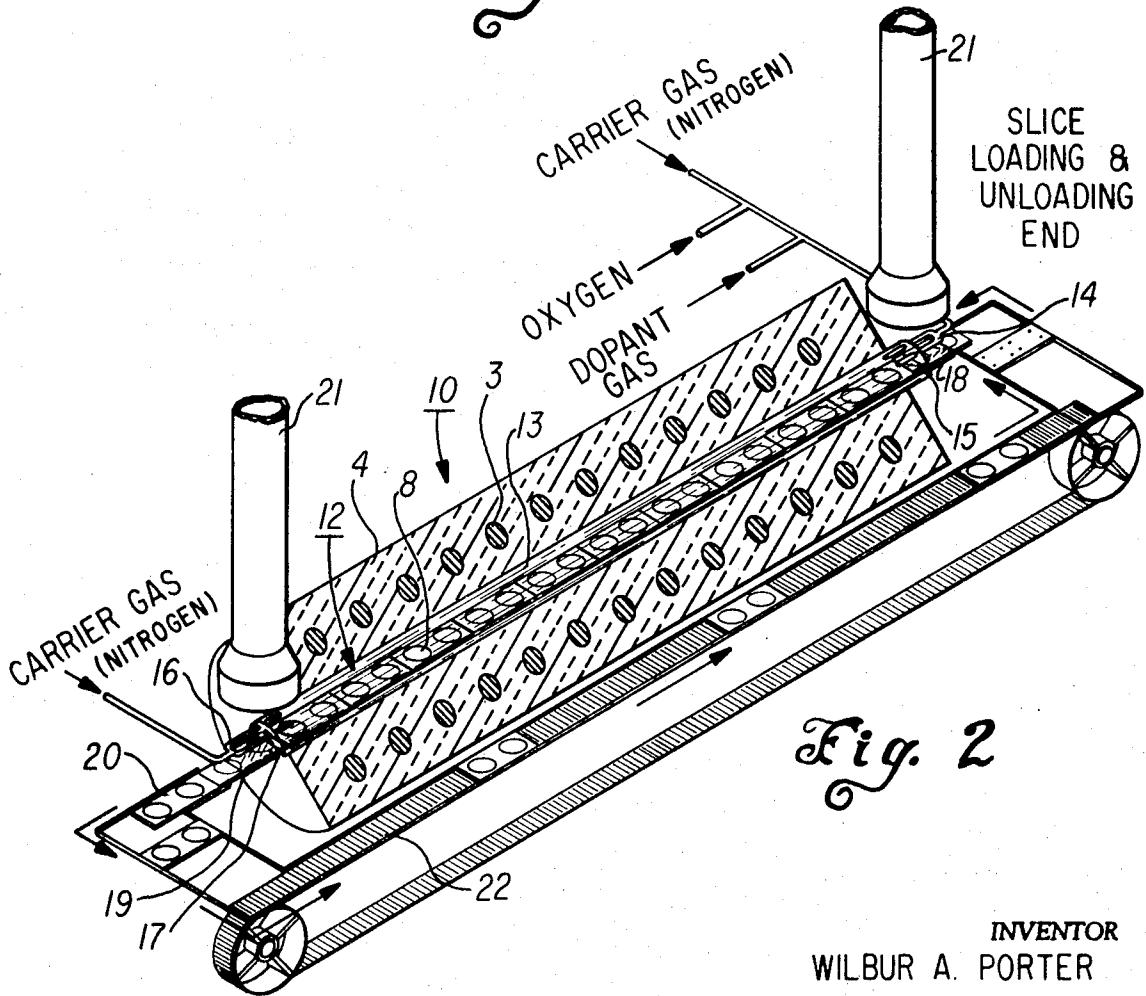


Fig. 2

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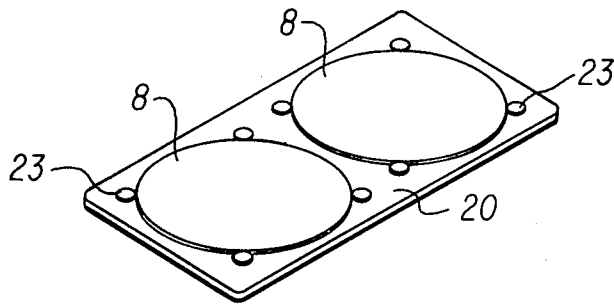


Fig. 3

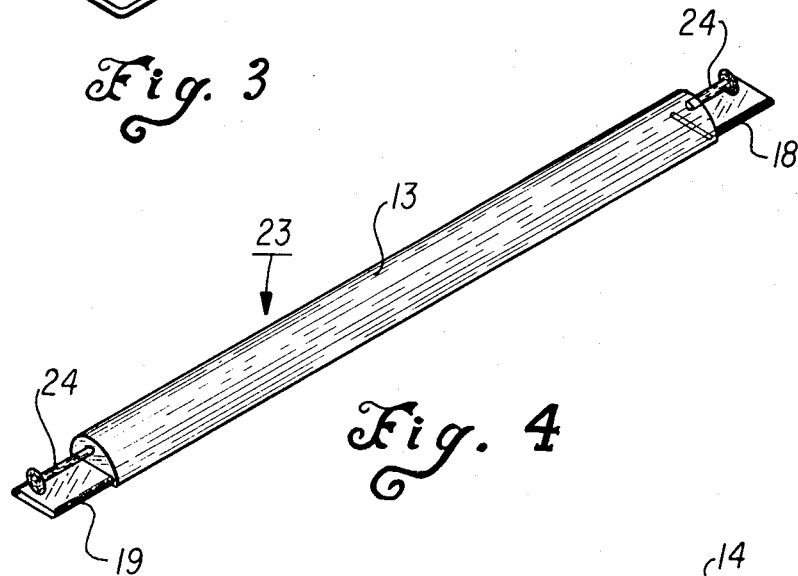


Fig. 4

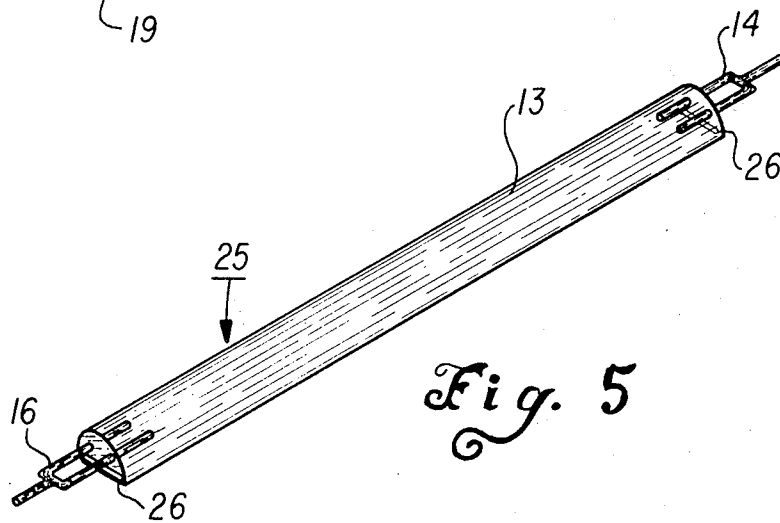


Fig. 5

CONTINUOUS DEPOSITION SYSTEM

This application is a continuation of application Ser. No. 756,186 filed Aug. 29, 1968.

This invention relates to semiconductor devices and more particularly to a system for the continuous deposition of a compound containing no impurity modifier on the surfaces of semiconductor slices prior to diffusing the impurity modifier from the compound into the slices for device fabrication.

In the fabrication of planar semiconductor devices it is necessary to form regions of a different conductivity type from the conductivity type of the semiconductor material of the slice. These regions are usually formed by a double step process comprising the deposition of a compound containing an impurity modifier on desired portions of the slice surface exposed by openings in a protective insulating layer on the surface followed by the heating of the slice for a period of time sufficient to diffuse the impurity modifier from the compound on the surface into the bulk of the slice to a desired depth. Both procedures utilize what is commonly known as the "batch" method.

In the deposition of the impurity modifier using this method, a small number of slices are placed vertically side-by-side in a holder, commonly called a boat. The boat is placed in a deposition chamber which is then closed at both ends except for a gas inlet and outlet. The deposition chamber is enclosed by a furnace which heats the slices located within to a desired deposition temperature. Gases containing an impurity modifier are introduced into the chamber for a period of time sufficient to deposit a layer of a compound containing the impurity modifier on a surface of each of the slices to a desired thickness. The boat containing the slices is then removed from the chamber from the same opening used to load the chamber. Both locating the boat in and removing the boat from the chamber are accomplished manually by a technician reaching into the chamber and gripping the boat with a long rod. The boat is then placed in a similar furnace called a diffusion furnace and heated in an oxidizing atmosphere for a period of time sufficient to diffuse the impurity modifier to the desired depth. Again, the introduction of the boat into the diffusion furnace and its subsequent removal is done manually.

Although the above described batch deposition and diffusion-oxidation methods have been used in the semiconductor industry for many years, there are a number of problems associated with the batch method. One of the problems is that since the loading and unloading of the furnace is done manually, the processing time must be controlled by setting a timer that signals a technician when the slices are ready to be removed. Failure to remove the slices on time due to the technician not reacting to the signal is a common occurrence.

Another undesirable feature of the batch process is that each slice is not exposed to the same environment. For such to be the case, uniform temperature and gas flow should be maintained throughout the processing zone, which uniformity is difficult to obtain in the batch process. In addition, the lack of temperature uniformity is complicated further due to the thermal shielding effect that the vertically standing slices have on one another. Uniform gas flow patterns across the surfaces of the slices are also difficult to maintain since the standing slices create flow constrictions within the

tube. Controlling the flow pattern within the tube is probably the most important function in obtaining uniformity of deposition. Because of the nonuniformity of temperature and gas flow, it is difficult to obtain much greater than ± 10 percent uniformity (as measured by sheet resistivity after the diffusion step is complete) across the surface of a single slice or from slice to slice when using the batch method.

Aside from the fact that slice temperature variations cause device parameters to vary in a given lot of slices, a more detrimental effect occurs as a result of slippage planes created due to thermal gradients which exist across the surface of a slice. When slippage planes occur, the atomic dislocation sites that are created diffuse at a faster rate than the diffusing atoms which causes emitter-collector shorts when the emitter region is being formed. Dislocations can be prevented by slow heating the slices entering and slow cooling the slices exiting the hot zone of the furnace. To eliminate the thermal gradients caused by slice shielding, the slices must be spaced at least 0.3 inch apart. Due to the need for the slow heating, slow cooling and spacing between slices, the resulting low volume of production rules out the elimination of thermal dislocations by this technique.

It is therefore an object of this invention to provide a system for depositing a uniform layer of a compound containing an impurity modifier on a surface of a semiconductor slice.

Another object of the invention is to provide a continuous deposition system for depositing a uniform layer of a compound containing an impurity modifier on a surface of each of a plurality of semiconductor slices passing sequentially through the system.

Yet another object of the invention is to provide an automated system for depositing a uniform layer of a compound containing an impurity modifier on a surface of each of a large number of semiconductor slices passing through the system.

A further object of the invention is to provide a system for depositing a uniform layer of a compound containing an impurity modifier on a surface of each of a plurality of semiconductor slices without creating slippage planes due to thermal gradients across the surfaces of the slices.

A still further object of the invention is to provide a continuous deposition tube for depositing a uniform layer of a compound containing an impurity modifier on a surface of each of a plurality of semiconductor slices passing sequentially through the tube.

A feature of the invention is that a layer of a compound containing an impurity modifier is deposited uniformly on a surface of each of a plurality of semiconductor slices by subjecting each slice to the same deposition environment. Each layer is uniformly deposited across a surface of each slice by the use of uniform gas flow patterns and the elimination of thermal shielding of the slices.

Other novel features believed to be characteristic of the invention are set forth in the appended claims. The invention itself, however, as well as other objects and advantages thereof may best be understood by reference to the following detailed description of illustrative embodiments when read in conjunction with the appended claims and accompanying drawings wherein:

FIG. 1 is a sectional view, illustrating a conventional prior art deposition furnace which utilizes the batch method.

FIG. 2 is a pictorial view, with a portion of the furnace cut away, illustrating the continuous deposition system of the invention, including the preferred embodiment of the deposition tube.

FIG. 3 is an isometric view, illustrating a typical deposition boat containing two semiconductor slices.

FIGS. 4 and 5 are isometric views, illustrating other embodiments of the deposition tube.

In brief, the continuous deposition system utilizes a deposition tube having a deposition chamber of hemitubular shape with a flat bottom. Double gas inlets extend into the chamber from opposite ends and entrance and exit portals extend out from opposite ends of the chamber, the portals having openings just large enough to admit deposition boats containing the semiconductor slices, the chamber being otherwise closed. The deposition chamber is partially enclosed by a suitable furnace so that the temperature of the semiconductor slices passing through the chamber can be raised to a desired deposition temperature.

A carrier gas such as nitrogen, oxygen and a doping gas containing an impurity modifier are introduced into the double gas inlets at the entrance end whereas only a carrier gas is introduced into the double inlets at the exit end. The deposition boats are loaded sequentially at the entrance end of the tube, each loaded boat containing two horizontally positioned slices.

The boats are pushed through the entrance portal into the deposition chamber where a uniform layer of a compound containing the impurity modifier is deposited on a surface of each slice and out of the chamber through the exit portal. A series of conveyors brings the boats exiting the tube back to the loading end of the system where the slices are unloaded, the empty boats repeating the deposition cycle. The slices are loaded from and unloaded into slice carriers automatically so that except for placing the slices in and retrieving the slices from the system, the system operates without any possibility of human error. The same system is used for diffusing the impurities into the semiconductor slices; however, because the flow patterns are not as critical within the diffusion tube, a much simpler hemitubular design can be used to reduce the cost of the system.

Referring now to the Figures of the drawings, there is shown in FIG. 1, a conventional prior art deposition furnace 1 which includes a tube, commonly made of quartz, defining the deposition chamber 2. The elements of FIG. 1 and the remainder of the Figures are not drawn to scale in order to emphasize certain elements for clarity of description. The tube is enclosed except for both ends by heating coils 3 positioned in an insulation medium 4 which are used to heat the semiconductor slices 8 within the chamber 2. The heating coils 3 are connected through a switch to a source of electric current (not shown). The chamber 2 has one end closed permanently except for a gas inlet 5. The loading end or opening 9 of the chamber 2 remains open while the slices are being introduced into the chamber and is closed during the deposition process by an end cap 6, having a gas exit 7, which is placed over the opening 9.

To operate the deposition furnace 1, a mixture of gases containing oxygen, a carrier gas, such as nitrogen and a dopant gas containing an impurity modifier is introduced into the chamber 2 through the gas inlet 5. The heating switch is turned on and electrical current is allowed to flow through the coils 3 to heat the chamber 2 to a predetermined deposition temperature.

A number of semiconductor slices 8 are then placed vertically on a deposition boat 11, also commonly made of quartz, for example, and placed into the deposition chamber 2 manually through the opening 9. The end cap 6 is placed over the opening 9 to enclose the slices.

As the gases flow past the slices 8 and escape through the gas exit 7, the impurity modifier in that dopant gas combines with oxygen on the hot surfaces of the slices to form an impurity modifier - oxygen compound on each surface, usually in the form of a layer of glass. The slices are allowed to remain in the deposition chamber 2 for a period of time sufficient to form the glass layer to a desired thickness and the boat 11 containing the slices is then removed. As can be seen from FIG. 1, the gas flow is constricted as it flows through the chamber 2 due to the vertical position of the slices, resulting in a nonuniform gas flow across each surface. The vertical slices also thermally shield one another, resulting in nonuniform temperatures from slice to slice. It is, thus, very difficult to obtain a very uniformly deposited layer across the surface of a single slice or uniformly deposited layers on different slices.

A continuous deposition system 10, including the preferred embodiment 12 of the deposition tube, is shown in FIG. 2. The deposition tube 12 has a deposition chamber 13 of hemitubular construction with a substantially flat bottom, as opposed to a pure tube design, the degree of flatness not being particularly important. The hemitubular shape causes the gases to flow only across the top surface of the slices whereas if a tubular shape was used there would be a gas passageway below the slices, causing the flow pattern of the gases to be more difficult to control within the chamber 13. Although other materials can be used for the deposition tube 10, the preferred material is quartz due to its relatively inertness in the deposition environment.

To achieve a uniform flow pattern of the gases through the chamber 13, double gas inlets 14 extend through the entrance end 15 into the chamber 13 and other double gas inlets 16 extend through the exit end 17 into the chamber 13. Test results have shown that better uniformity is achieved with double inlets rather than with single inlets and with inlets in both ends of the chamber 13 rather than with inlets in only one end. Also, test results have shown that for better uniformity the double inlets 14 and 16 should extend into the chamber 13 for about 4 inches to allow the entering gases to achieve proper heating before flowing across the slices.

An entrance portal 18 is connected to and extends from the entrance end 15 of the chamber 13 and an exit portal 19 is connected to and extends from the exit end 17 of the chamber 13. For optimum doping, the length of the portals should be about 4 inches, test results having shown that portals of shorter length cause decreased doping of the slices. Both portals 18 and 19

are located below the gas inlets 14 and 16, respectively, and are positioned such that the bottom wall of each portal is flush with the bottom wall of the chamber 13, thereby furnishing smooth transition of the boats between the portals 18 and 19 and the chamber 13. The inside dimensions of both portals are designed so as to just allow the passage of the slice loaded boats 20; enough room remains for the gases to escape through the portals. Exhausts 21 are located above the entrance and exit ends of the deposition tube 12 to collect and remove the gases flowing from the chamber 13 through the portals 18 and 19. The deposition tube 12 is enclosed, except for the ends 15 and 17 of the chamber 13, by the insulating material 4 and by heating coils 3 which are connected to a source of electrical current (not shown). A conveyor system 22, which is not shown in great detail, is utilized to convey the boats exiting from the exit portal 19 of tube 12 and return them, after the slices have been removed from the boats, to the entrance portal 18 to repeat the deposition cycle.

In the operation of the system 10, the deposition chamber 13 is heated to a desired temperature by the heating coils 3, which temperature has been predetermined so as to heat the surface of each slice 8 when it passes through the chamber to a desired deposition temperature. For a P conductivity-type deposition, oxygen, a carrier gas, such as nitrogen, and a dopant gas, such as boron tribromine (BBr_3), which is derived from a liquid source, are introduced into the double inlets 14, boron being the impurity modifier. Although the same mixture of gases can be introduced into the double inlets 16, the flow of these gases are not needed, and, therefore, just the carrier gas is normally passed through inlets 16, mainly to act as a pattern generator that contributes to the uniform gas pattern within the chamber 13. The gases exit the deposition chamber 13 through the portals 18 and 19. An earlier model of the deposition tube 12 had gas flushing vents (not shown) connected to the entrance and exit portals to allow the gas to escape, but it was found that the flushing vents were not needed, the portals 18 and 19 furnishing sufficient escape openings for the exiting gases.

It has been found that for P conductivity-type depositions on silicon slices, a single set of gas flows furnishes uniform depositions over the temperature range of about 800°C to about 1200°C . Typical gas flows are 3.5 liters/min. of nitrogen through inlet 16 and 3.5 liters/min. of nitrogen, 20 c.c./min. of oxygen and 6 c.c./min. of nitrogen bubbled through a liquid source of boron tribromine through inlet 14.

For N conductivity-type depositions on silicon slices, the same flow rates are not used for all deposition temperatures. In the range of between about 775°C to about 900°C , flow rates of 2.75 liters/min. of nitrogen through inlet 16 and 2.75 liters/min. of nitrogen, 80 c.c./min. of oxygen and 120 c.c./min. of nitrogen bubbled through a liquid source of phosphorous oxychloride (POCl_3) through inlet 14 are appropriate. Between about 900°C to about 1200°C , flow rates of 3.25 liters/min. of nitrogen through inlet 16 and 3.25 liters/min. of nitrogen, 180 c.c./min. of oxygen and 180 c.c./min. of nitrogen bubbled through a liquid source of phosphorous oxychloride through inlet 14 are needed.

To begin the deposition cycle, an empty deposition boat 20 is placed on a support at the loading end of the

system in front of the entrance portal 18. One type of deposition boat, which is more clearly shown in FIG. 3, is a flat boat with space on its top surface for two slices to be positioned side by side. Two slices 8 are positioned horizontally on the boat by locating pins 23 which project above the top surface of the boat. The boat 20 can be made of quartz, for example. However, a more desirable boat material is silicon carbide coated graphite because there is a smaller coefficient of friction between silicon carbide and quartz than between quartz and quartz. A choice of boat material is very critical for when the quartz tube is filled with boats, as it is during the process, the frictional forces become very important. These frictional forces determine the operational time before cleaning the tube 12 becomes necessary, which is costly and time consuming and, therefore, should be minimized. It is for this reason that boat material other than quartz is preferred. The temperature of the chamber 13 is such that the center of the flat bottom sags somewhat so that only the bottom edges of the boats ride on the bottom surface of the tube, thus decreasing the frictional forces between the chamber 13 and the boats 20.

The continuous deposition system has been designed so that all mechanical aspects of loading and unloading remain outside of the deposition tube 12. This is done to reduce impurities within the tube as no material, other than quartz, has been found that can withstand the chemical and thermal environment within the deposition chamber 13 for a long period of time and maintain a high level of purity. Although it may be possible to develop a belt type carrier for the slices rather than use a "pusher" system with boats, no belt material has been found that can withstand the extreme environment within the tube. The empty boats are loaded automatically at the loading end of the system by a slice carrier (not shown), described fully in the copending application of Wallace O. Wells, filed Mar. 8, 1968, Ser. No. 711,589 and assigned to the same assignee of the present application. The driving force for the boats is supplied by a drive motor (not shown) connected by a drive mechanism (not shown) which contacts the loaded boat positioned in front of the entrance portal 18. Each boat pushes the preceding boat in a train-like fashion through the tube 12, the driving force being supplied by the drive mechanism to the last boat in the train.

As the slices 8 travel through the deposition chamber 12 their surface temperature rises sufficiently to cause the impurity modifier, P conductivity-type boron, when boron trichloride is used as the dopant, or N conductivity-type phosphorous, when phosphorous oxychloride is used as the dopant, to disassociate from the dopant gas, react with the oxygen and silicon present and deposit on the hot surface of the slices as a boron-silicate glass-like compound in the case of boron and as a phospho-silicate glass-like compound in the case of phosphorous when silicon slices are used. The rate of travel of the slices through the tube, along with the flow rate and concentration of the gases, determines the deposition rate of the doping layer on the surface of the slices. These parameters are predetermined before the deposition cycle is begun and are changed depending upon the desired sheet resistivity of the diffused slice following the subsequent diffusion-oxidation step. The

slice loaded boats exit the deposition tube 12 through the exit portal 19 and are conveyed by the conveyor system 22 back to the unloading end of the deposition system 10 where the slices are automatically removed from the boats and returned to a slice carrier (not shown). The empty boats are then conveyed back to the beginning point in front of the entrance portal 18 and reloaded with new semiconductor slices to repeat the deposition cycle.

Although the preferred embodiment of the deposition tube is the tube 12, as shown in FIG. 2, which is used for the maximum in uniformity and flexibility, a tube 23, less exacting in its construction, is shown in FIG. 4. The tube 23, which can be used also for diffusion-oxidation, has the same hemitubular shape chamber 13 as did tube 12. An entrance portal 18 extends from one end of the chamber 13 and an exit portal 19 extends from the opposite end of the chamber. When the need for gas back pressure in the chamber 13 is not so great, such as when high sheet resistivities are desired, the extended portals 18 and 19 can be eliminated or reduced in length. Single gas inlets 24 open into both ends of the chamber 13 but do not extend into the chamber 23 and thus do not heat the entering gases before they pass into the chamber 13 itself. The single gas inlets 24 do not give as uniform a flow pattern within the chamber 13 as the double inlets, as shown in FIG. 2, but can be used, especially in the diffusion-oxidation operation, where the flow pattern of the gases within the chamber is not too critical.

Still another embodiment 25 of a deposition tube is shown in FIG. 5. The chamber 13 has the same hemitubular shape as the deposition tubes 12 and 23. The deposition tube 25 has entrance and exit portals 26 which do not extend from the hemitubular chamber 13. Instead, the closed ends of the chamber 13 have openings or portals 26 sufficient to allow the boats to enter and exit the chamber 13. Double gas inlets 14 and 16 extend into opposite ends of chamber 13 and are of sufficient length to preheat the entering gases. Due to the lack of back pressure caused by the lack of extended exit and entrance portals, as shown in previous embodiments, high doping levels are not obtained by

using the deposition tube 25, especially at low temperatures, such as below 900°C.

Every possible combination of single or double gas inlets combined with different types of entrance and exit portals has not been described for conservation of space for it is obvious that the hemitubular deposition chamber can be used with any combination of gas inlets and portals and still remain within the purview of the invention. Therefore, although only a preferred embodiment of the invention has been described in detail with two alternate embodiments of the deposition tube, it be understood that various changes, substitutions, and alterations can be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. A system for depositing a compound on a surface of each of a plurality of semiconductor slices, comprising in combination:

- a. a deposition chamber of hemitubular construction disposed within furnace means and having entrance and exit portals;
- b. at least first and second gas inlets passing through each of the two end walls of, and extending substantially into, said deposition chamber, whereby a gas passing through said inlets is preheated;
- c. means for passing boats containing horizontally positioned slices through said entrance portal, through said chamber and out said exit portal at a controlled rate; and
- d. means enclosing said chamber for heating said slices to a predetermined deposition temperature to form said compound on a surface of each of said slices as said slices pass through said chamber by decomposition of a gas, said gas entering said deposition chamber through said gas inlets and exiting said deposition chamber through said entrance and exit portals.

2. A system in accordance with claim 1 wherein both entrance and exit portals extend from said chamber about four inches, the openings of said portals being restricted in size to generally the dimensions of said boats.

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