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FURNACE FOR TREATING MATERIAL IN A GAS ATMOSPHERE

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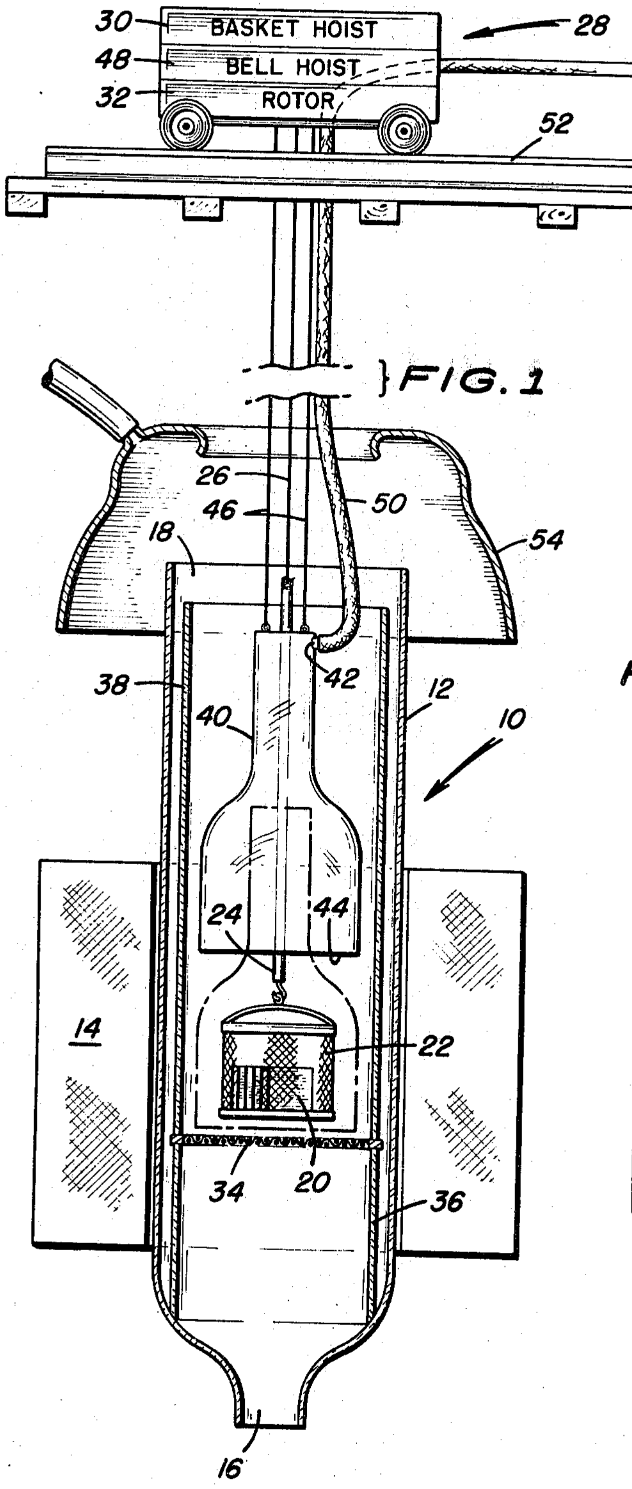
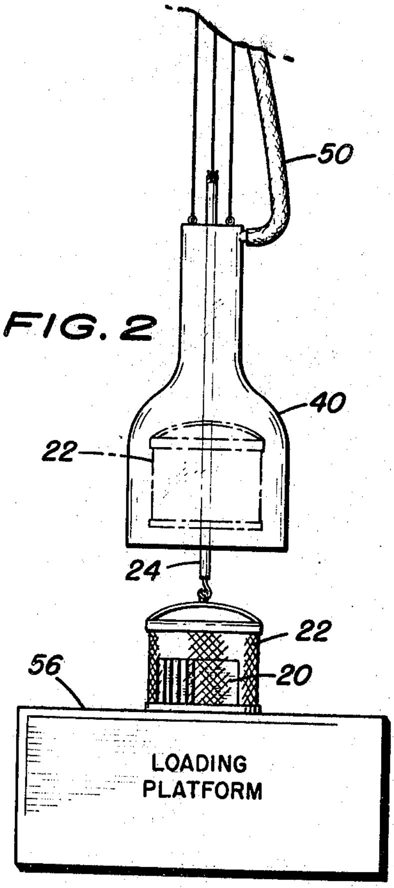


FIG. 1

FIG. 2



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FURNACE FOR TREATING MATERIAL IN A GAS ATMOSPHERE

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U.S. Cl. 263—41 **10 Claims**

ABSTRACT OF THE DISCLOSURE

A furnace useful in treating semiconductor wafers by means of a gas atmosphere. The furnace is oriented vertically and comprises an outer chamber provided with gas inlet and gas outlet ports; means for creating turbulence in the admitted gas and means for imparting motion to the wafers to insure that the wafers are uniformly acted upon by the gas; means for providing the wafers with an inert gas cover when no treatment is desired; and means for safely removing residual gas from the furnace.

BACKGROUND OF THE INVENTION

Field of the invention

The subject invention relates to a furnace which is of the type wherein a gas is admitted into one end of a vertical chamber and is extracted from the other end of said chamber. While the gas flows through the chamber, it comes into contact with and treats a plurality of semiconductor wafers suspended in the center of said chamber. Surrounding the vertical chamber, and maintaining the wafers at an elevated temperature during the treatment, is a heating element. Also provided, are means for creating turbulence in the gas to insure uniform contact with the suspended wafers and means for providing an inert gas cover to protect the wafers from the treating gas at times when no treatment is desired.

Description of the prior art

The semiconductor furnaces which are used throughout the industry are generally of the horizontally oriented variety. A representative furnace of this type is shown in U.S. Patent No. 2,804,405, issued to Derick et al. on Aug. 27, 1957. In operation, a plurality of semiconductor wafers are placed on a tray, or boat, and are slid into the horizontal chamber of the furnace. A gas valve delivers treating gas to the chamber and said gas flows through the horizontal chamber and comes in contact with and treats the semiconductor wafers housed therein. While this type of furnace proves to be adequate for present day semiconductor technology, there are many drawbacks which cannot be overlooked. Among these drawbacks are the following. When the boat is slid into and out of the furnace, the wafers are often contaminated by flaking deposits falling from the wall of the heating chamber; the thermal lag, or recovery time, resulting from the insertion of a "cold" boat and its associated wafers into the chamber of the furnace adversely affects the treating process; it is difficult to uniformly treat the semiconductor wafers since the flow of treating gas through the chamber and the centering of the wafers within the chamber are very difficult to control; the horizontal furnace does not lend itself to automation; it is difficult to sample the temperature within the working area of the chamber since such a sampling is dependent upon an accurate positioning of a temperature-sensing thermocouple; and in the horizontal furnace it is difficult to control the residual gas after it is expelled from the chamber.

While there are several embodiments of vertical furnaces forming part of the prior art, these embodiments have not eliminated all of the drawbacks associated with the horizontal furnace. Examples of vertical furnaces known to the prior art can be found in U.S. Patent No. 2,834,697, issued to Smits on May 13, 1958, U.S. Patent No. 3,113,056, issued to Van Doorn on Dec. 3, 1963 and U.S. Patent No. 3,180,755 issued to Reinitz on Apr. 27, 1965. In each of these examples of vertical furnaces, one or more of the following disadvantages remain. The recovery time adversely affects the operation of the furnace; uniform treatment of the semiconductor wafers is not attained; and automation is difficult, if not impossible, to achieve. Furthermore, in all but Reinitz, something other than an all gas atmosphere (which is inherently clean and is relatively easy to control) is used; and even in Reinitz, there is much room left for reducing the risk of injury to attendant personnel.

SUMMARY OF THE INVENTION

The subject invention relates to a vertical furnace for treating semiconductor wafers by the means of a pure gas atmosphere. Due to the vertical orientation of the subject furnace, many advantages present themselves, the most important of these being that the semiconductor wafers treated in the furnace of the subject invention are treated uniformly and that there is only a small risk to attendant personnel. The first advantage is obtained by creating turbulence in the gas atmosphere surrounding the wafers and by causing the wafers to move through the gas atmosphere; and the second advantage is realized by the fact that the instant furnace is largely automated. Another advantage of the subject furnace lies in its capability for accurately controlling the time that the wafers come into contact with the treating gas. This advantage is obtained by providing the wafers with an inert gas cover which can easily and accurately be applied or removed. Therefore, while the furnace is going through what is called temperature recovery, the inert cover is applied to the wafers, said cover being removed only after the furnace attains ideal operating conditions. The gas cover also proves useful during various stages of the treating operation in preventing the wafers from coming in contact with undesirable contaminants. Other advantages of the instant furnace are that it provides means for easily sampling the operating temperature, it is far cleaner than are the furnaces of the prior art, and its maintenance costs are less than those associated with the furnaces of the prior art. In addition to these advantages, the furnace of the subject invention is quite versatile, not being limited to the semiconductor field.

It is therefore an object of the invention to provide a versatile treating furnace.

It is a further object of the invention to provide a furnace which uniformly treats semiconductor wafers housed therein.

It is another object of the invention to provide a pure gas atmosphere furnace which uniformly treats semiconductor wafers housed therein.

It is still a further object of the invention to provide a semiconductor furnace which is easily adaptable to automation.

It is still another object of the invention to provide a semiconductor furnace which is inherently safe to attendant personnel.

It is yet a further object of the invention to provide a semiconductor furnace which is relatively inexpensive to maintain.

It is yet another object of the invention to provide a furnace for treating semiconductor wafers wherein the treatment can be accurately controlled.

It is still a further object of the invention to provide a furnace which avoids undesirable contamination of semiconductor wafers to be treated.

These and other objects of the invention, as well as many of the attendant advantages thereof, will become more evident when reference is made to the following discussion, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic representation of the subject furnace during a typical treating operation; and

FIG. 2 is a schematic representation of the wafer loading and unloading operations involved in the practice of the instant invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Before a detailed description of the subject invention is undertaken, it should be noted that while the furnace is explained as being a semiconductor diffusion furnace, this is done only for simplicity. In fact, the subject furnace is quite versatile, having uses both in the semiconductor field and in other fields. The furnace of the subject invention, just to mention a few applications, can serve as a semiconductor diffusion furnace, a semiconductor oxidation furnace and a "drive-in" furnace for distributing the doping in a semiconductor wafer. Outside the semiconductor field, the instant furnace is useful in many ceramic treating operations and a host of other gas-treating applications which will become readily apparent to those skilled in the art.

With reference first to FIG. 1, there is shown the furnace of the subject invention during a typical treating operation. The furnace is shown generally at **10** and comprises a vertically oriented heating chamber **12** around which is positioned a source of heat **14**. The chamber **12** is conveniently a right circular cylinder and has a gas inlet **16** at its lower end and a gas outlet **18** at its upper end. The inlet **16** serves as an entrance for a supply of treating gas which passes through the chamber **12** and which exits at the outlet **18** after coming in contact with the material to be treated—for simplicity, semiconductor wafers **20**. The wafers **20** are placed in a basket **22** which is suspended along the axis of the chamber **12** by a rod **24** and a wire **26**. The end of the wire **26** remote from the rod **24** passes into a control system shown generally at **28**. Within the control system **28**, the wire **26** is associated with a basket hoist **30** for raising and lowering the basket **22** into and out of the chamber **12** and is further associated with a rotor **32** for imparting rotational motion to the basket **22** when said basket is within the chamber **12**.

To insure that the wafers **20** are uniformly diffused by the gas passing from the inlet **16** to the outlet **18**, a screen **34** is placed across the chamber **12**. When the gas passes through the chamber **12**, it is forced through screen **34** and experiences turbulence as it flows through what shall be called the treating region—the region in which the wafers are placed during the diffusion operation. The combined action of the rotating wafers and the turbulent gas guarantees that every part of the wafer surface is diffused alike. To insure that the screen **34** remains in a proper position for creating the necessary gas turbulence, somewhere between the inlet **16** and the center of the treating region, the furnace **10** is provided with a spacer element **36** which abuts the inlet **16** and which supports the screen **34**. Also supported by the spacer element **36** is a removable liner **38**, the liner being adapted for easy replacement after it becomes impregnated with the diffusing gas. By providing the furnace with such a removable liner, only the liner needs periodic replacement, thereby avoiding costly replacement of the entire chamber **12**.

When cold (room temperature) semiconductor wafers are inserted into the chamber of a diffusion furnace, the furnace temperature could drop as much as 200° C. from the ideal operating temperature which is of the order of 1000° C. Once this decrease in temperature occurs, it often requires as much as **10** minutes for the temperature to reach its original level—this time is termed the thermal lag or the recovery time. It has been the experience that an inferior diffusion results if the wafers are treated during this recovery time. Therefore, the furnace of the subject invention is provided with means for protecting the wafers against contact with the diffusion gas during the recovery time. More particularly, the subject furnace is provided with a bell jar **40** having a gas inlet **42** at its upper end and a gas outlet **44** at its lower and flared end. The jar **40** is supported by wires **46**. The ends of the wires **46** remote from the jar **40** lead into the control system **28** and are associated with a bell hoist **48**—hoist **48** providing the capability of moving the bell jar **40** into and out of the furnace independent of the basket **22**. As noted above, the function of the bell jar **40** is to protect the wafers **20** from the diffusion gas during temperature recovery. This is accomplished by providing the wafers with an inert gas cover. More particularly, a supply of inert gas is fed to an inlet **42** of the bell jar **40** through a flexible tube **50**; and when the jar **40** is placed over the wafers **20**, the downward pressure of the inert gas (which is made greater than the upward pressure of the treating gas) protects the wafers against contact with the diffusion gas.

While the above-discussion deals only with the recovery time, it is advantageous to cover the wafers with the inert gas at all times, save for when the wafers are being treated. By covering the wafers before and after the treating operation, the wafers are kept free from dust and other foreign matter, and the system is provided with an added degree of accuracy—the bell jar can be raised above the wafers when treatment is desired and can be dropped over the wafers at precisely the instant in time when the treating operation is completed, making both the commencement and the termination of the treating operation easily and accurately controllable.

As previously stated, the furnace of the subject invention is easily adapted for automation. It is readily seen that the basket containing the wafers to be diffused can automatically be lowered into or raised from the furnace by the basket hoist, and can automatically be revolved, once in the furnace, by the rotor. It is also readily seen that the bell jar can, independent of the basket, be raised or lowered by the bell hoist. The subject furnace is also provided with means for automatically moving the bell jar **40** and the basket **22** between a loading platform remote from the furnace and the furnace itself. More particularly, the control system **28** can conveniently take the form of a car, movable on a set of rails **52**. Therefore, a loaded basket can travel from a loading platform to the furnace, be treated and then return to the loading platform in the absence of the human factor. By eliminating the need for attendant personnel during these operations, it is obvious that the subject furnace has a safety factor far in excess of that associated with the furnaces presently used in the semiconductor industry. To further increase the safety factor, the furnace is provided with an exhaust hood **54** which serves to remove the treating gas from the vicinity of the furnace after the gas has been used for treating. In the alternative, if room permits, the entire furnace assembly can be located in a gas exhaust room remote from the operator, obviating the need for an exhaust hood. By employing either of the above-noted gas removal schemes, it is obvious that the operator is protected, to a great extent, against contact with the treating gas; and therefore, it is equally obvious that the furnace of the subject invention eliminates many hazards associated with conventional all gas material-treating furnaces.

With the concurrent references now to FIGS. 1 and 2, the steps involved in operating the subject furnace will be outlined. The operation begins at a loading platform **56** when the basket **22** is loaded with a supply of semiconductor wafers **20**—the bell jar **40** being slightly remote from the basket **22** (FIG. 2). Then the basket hoist **30** is activated, causing the basket **22** to retreat into the jar **40**. Once the basket **22** is within the jar **40** (shown in phantom), the bell hoist **48** is activated—the basket hoist **30** and the bell hoist **48** operating concurrently until the jar and the basket are at a height sufficient to clear the exhaust hood, at which time they are both inactivated. The control system **28** is then caused to move along the track **52** until the jar **40** and the basket **22** are directly over the chamber **12**. During this entire operation, the furnace **10** is at its operating temperature, the tube **50** is feeding the jar **40** with inert gas and, if desired, treating gas is flowing through the chamber **12**. The bell hoist **48** and the basket hoist **30** are then again activated, this time lowering both the bell jar **40** and the basket **22** into the furnace until the basket is in the treating region (shown in phantom in FIG. 1), at which time the basket hoist and the bell hoist are both inactivated. Then the rotor **32** is activated, causing the basket **22** to rotate within the treating region. At the end of the recovery time, that is, when the furnace once again reaches its operating temperature, the bell hoist **48** is activated, raising the jar **40** an amount sufficient to allow the treating gas to act upon the wafers **20**. After the diffusion operation is completed, the bell hoist causes the jar **40** to lower over the basket **22**, again covering the wafers **20** with an inert gas cover. The basket and bell jar are then, together, through the means of the basket hoist **30** and the bell hoist **48**, raised from the furnace **10** an amount sufficient to clear the exhaust hood. The rotor **32** is then inactivated, as there is no need to sustain the rotational motion in the basket **22** once the basket is outside the furnace. The control system **28** is then caused to travel along the tracks **52** until the basket and the bell jar are again over the loading platform. The basket **22** and the jar **40** are then concurrently lowered until they reach a height slightly above the surface of the loading platform, at which time the jar **40** stops its journey (shown in FIG. 2). The basket **22** continues its downward trip until it reaches the surface of the loading platform, at which time the diffused wafers are removed from the basket **22** and are replaced by a fresh supply of semiconductor wafers. The diffusion operation is then repeated for these new wafers.

In summary, there has been disclosed a versatile furnace which is readily adapted to automation and which is therefore inherently safe to attendant personnel. Further, there has been disclosed a furnace which can accurately and uniformly treat a large number of materials by an all-gas atmosphere in an economic and extremely clean manner. However, it should be understood that the specific furnace disclosed and the specific treating operation disclosed are merely illustrative of the principles of the instant invention and that numerous other applications and variations may be devised by those skilled in the art without departing from the spirit and scope of the invention.

We claim:

1. An all gas material treating furnace comprising,
a vertically oriented heating chamber having a gas inlet at one end for the introduction of treating gas, a gas outlet at the opposite end for the discharge of treating gas and a treating region intermediate said gas inlet and said gas outlet,
means for delivering heat to said treating region,
means for suspending material to be treated within said treating region in such a manner that there will be no contact by such material with said heating chamber,
means for inducing turbulence in the treating gas while said gas passes through the treating region,
and means for rotating the material suspending means, said last-mentioned means cooperating with said turbulence inducing means for assuring even flow of treating gas about the material to be treated.

2. The furnace as recited in claim **1** and further comprising
means for providing an inert gas cover for the material to be treated so that when said cover is present, the material is protected against the treating gas.

3. The material-treating furnace of claim **2** and further comprising
means for inserting the material to be treated into the heating chamber in the presence of said inert gas cover and
means for withdrawing the material from the heating chamber, after treatment, in the presence of said inert gas cover.

4. The material-treating furnace as recited in claim **3** wherein
said means for inducing turbulence in the treating gas is a screen through which said treating gas is forced to flow.

5. The furnace of claim **4** and further comprising
a spacer element for positioning said turbulence inducing screen intermediate said gas inlet and the center of said treating region and
a removable liner extending substantially the length of the treating region for protecting the wall of the heating chamber against contact with the treating gas.

6. The furnace of claim **5** wherein said heating chamber is a right circular cylinder of a first diameter and said removable liner as a right circular cylinder of a second and lesser diameter.

7. The treating furnace of claim **5** and further comprising
a gas exhaust hood adjacent the gas outlet of the heating chamber for removing the treating gas from the vicinity of the furnace.

8. The material-treating furnace as recited in claim **2** wherein said means for providing an inert gas cover comprises
a movable jar which is capable of encompassing the material to be treated and having
a gas inlet at one end for the introduction of an inert gas and
a gas outlet at the opposite end for the discharge of an inert gas;
whereby the material to be treated is protected against contact with the treating gas when said jar encompasses said material, but whereby the material is acted upon by said treating gas when said jar is remote from said material.

9. An all gas material-treating furnace comprising
a vertically oriented right circular cylindrical heating chamber having
a gas inlet at one end for the introduction of treating gas,
a gas outlet at the opposite end for the discharge of treating gas and
a treating region intermediate said gas inlet and said gas outlet;
heating means surrounding said heating chamber for delivering heat to said treating region;
turbulence unducing means for causing the treating gas flowing from said gas inlet to said gas outlet to exhibit turbulence while passing through said treating region;
a jar capable of being lowered into said heating chamber and having
a gas inlet at one end for the introduction of an inert cover gas and

a gas outlet at the opposite end for the discharge of said inert cover gas;

housing means capable of being lowered into said heating chamber for carrying the material to be treated;

means for raising and lowering said housing means relative to said heating chamber;

means for imparting rotational motion to said housing means; and

means for raising and lowering said jar relative to said heating chamber and relative to said housing means.

10. A method for treating a material by a gas atmosphere in the presence of heat and comprising the steps of

loading the material to be treated onto a movable housing;

covering the material to be treated with an inert gas atmosphere;

lowering said movable housing into a heating chamber taking care not to contact the chamber wall with the housing while at the same time maintaining said inert gas cover over the material to be treated;

passing a treating gas through the heating chamber;

maintaining the inert gas cover over the material to be treated while said heating chamber is approaching the ideal operating temperature;

inducing turbulence in the treating gas as it passes through said heating chamber;

imparting rotational motion to said movable housing;

removing said inert gas cover when the heating chamber reaches the ideal operating temperature, thereby allowing the material to be treated to be acted upon by said treating gas;

covering the material, after treatment is completed, with an inert gas atmosphere;

raising said movable housing out of said heating chamber taking care not to contact the chamber wall with the housing while at the same time maintaining said inert gas cover over the treated material;

removing said inert gas cover; and

unloading the treated material from said movable housing.

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JOHN J. CAMBY, Primary Examiner

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