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Anderson

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[54] **RAPID TEMPERATURE RESPONSE WAFER CHUCK**

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Related U.S. Application Data

[63] Continuation of Ser. No. 587,718, Sep. 25, 1990, abandoned.

[51] **Int. Cl.**^{5} **F25B 19/02;** F25B 29/00

[52] **U.S. Cl.** **165/61;** 62/51.1; 62/52.1; 118/724; 118/725; 118/728; 165/64; 165/80.4; 165/104.33; 165/908; 165/911; 250/492.2

[58] **Field of Search** 165/908, 104.33, 911, 165/61, 64, 80.4; 118/724, 725, 728; 250/492.2; 62/51.1, 52.1

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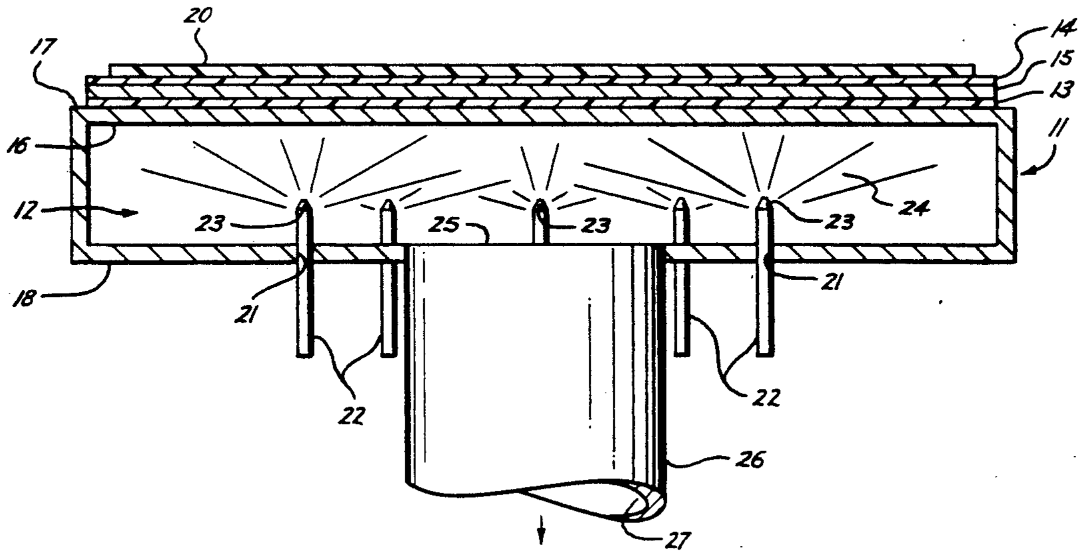
Attorney, Agent, or Firm—William W. Kidd

[57] **ABSTRACT**

A wafer chuck having a substantially hollow cavity therein utilizes the latent vaporization of a liquid to extract heat from the wafer. An insulated heater provides for heating the wafer to its desired operating point as rapidly as possible in order to bring the wafer to its operating point before plasma etching or deposition occurs.

12 Claims, 2 Drawing Sheets



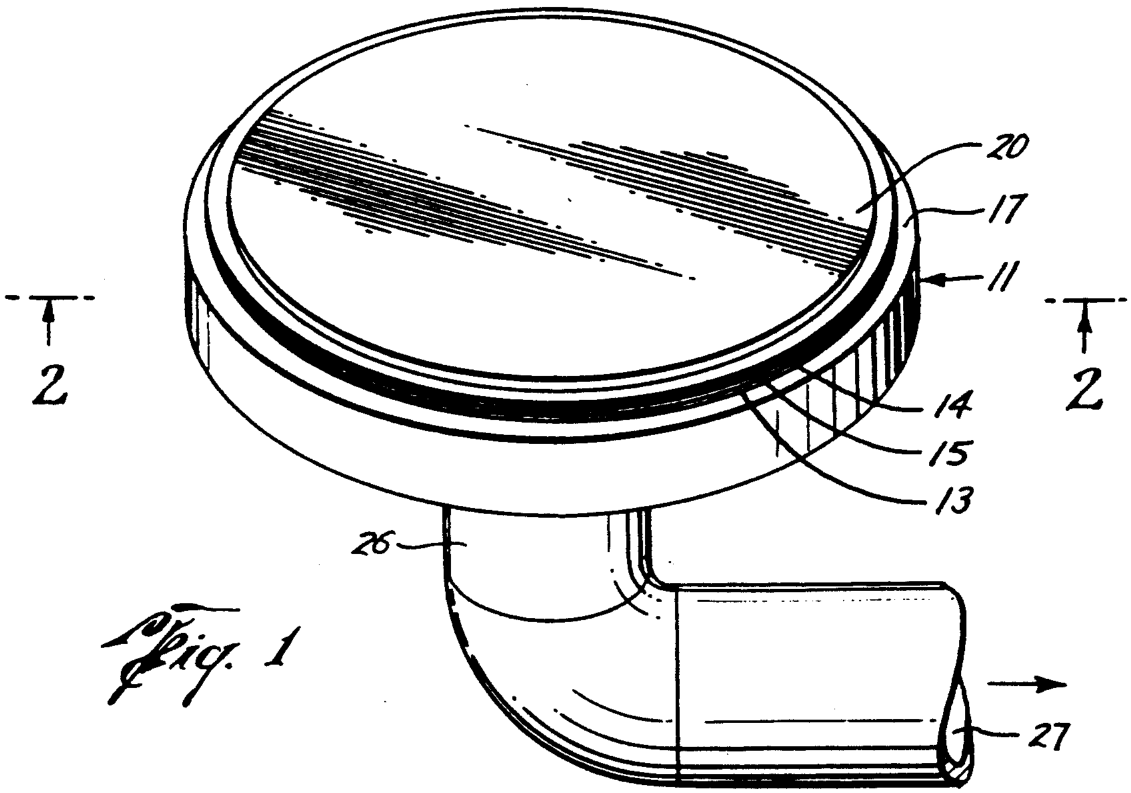


Fig. 1

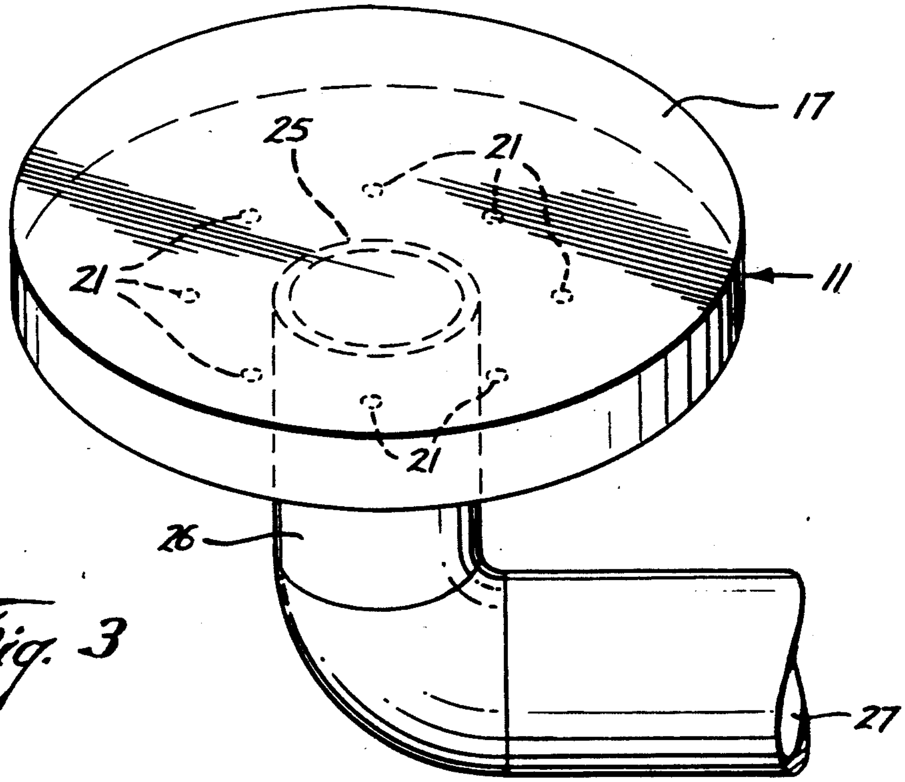


Fig. 3

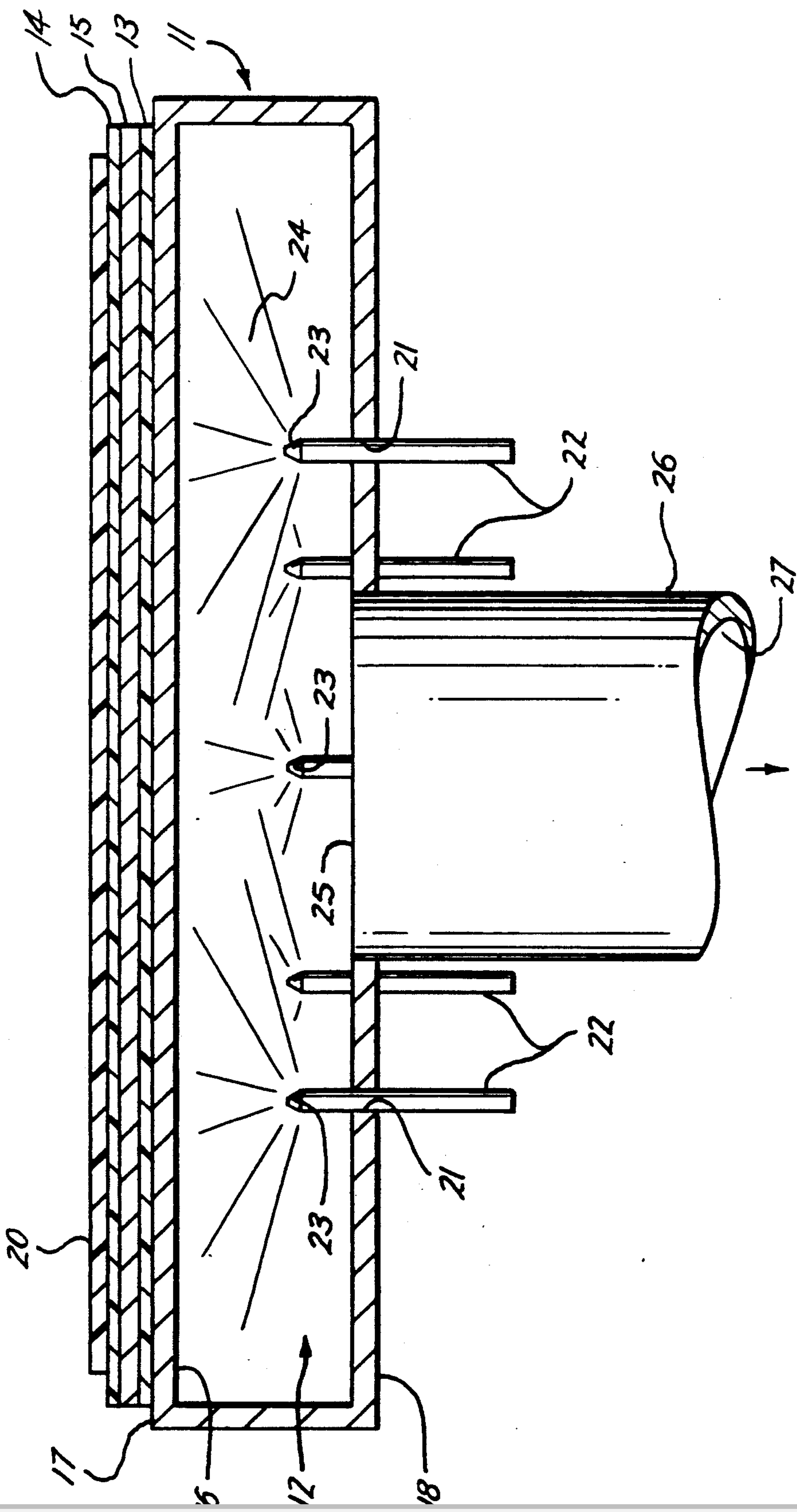


Fig. 2

RAPID TEMPERATURE RESPONSE WAFER CHUCK

This application is a continuation of application Ser. No. 587,718, filed on Sep. 25, 1990, now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to the field of semiconductor manufacturing devices and, more particularly, to chucks for controlling wafer temperature.

2. Prior Art

In the manufacture of semiconductor integrated circuit devices, various circuit elements are formed in or on a base substrate, such as a silicon substrate. Generally, the process of forming these various circuit elements starts from a base wafer, which is typically flat and is circular in shape. On each of these flat circular wafers, a number of integrated circuit devices, typically known as "chips" are formed by the use of various well-known techniques, including photolithography, doping, depositing, etching, and annealing techniques, just to name a few.

In performing some of these steps, a wafer is placed in a chamber in order for the wafer to undergo a necessary processing step, such as deposition or etching. When these wafers are loaded into a given chamber, the wafer is placed on a wafer chuck, which is a type of semiconductor platen. These platens, or chucks, are used to control the wafer temperature during a given process cycle. Because the wafer resides on the platen, by controlling the temperature of the platen, wafer temperature can be controlled. Accordingly, elaborate measures have been devised to address the various means available for controlling the temperature of the platen. Some of these prior art techniques are described in U.S. Pat. Nos. 3,501,356; 4,496,609; 3,669,812; 4,542,298; 4,628,991; 4,671,204; 4,457,359; 4,282,924; and 3,885,061. These patents teach a technique of cooling the wafer by circulating liquids, such as water. Either the cooling of the apparatus as a whole is provided by the circulating cooling water, or in more sophisticated systems, channels or passages are provided in the base of the chuck to directly cool the wafer chuck.

Another prior art device is described in U.S. Pat. No. 4,274,476, in which heat created inside the wafer is transferred to an expandable heat pipe, wherein the heat causes the fluid in the heat pipe to boil and vaporize. The vaporizable liquid is inside the cavity for expanding the heat pipe when heated and for transferring heat from one plate to the other. Furthermore, another scheme is described in U.S. Pat. No. 3,724,536, in which a fluid coolant, such as carbon dioxide, undergoes a rapid expansion upon entering an expansion chamber, thereby cooling the conductive element and consequently the device under control.

In practice, the temperature of the chuck must frequently be controlled at a temperature substantially below that of the wafer process temperature, especially when there is substantial energy input into the wafer. Substantial energy input to the wafer will usually occur when processing techniques such as plasma etch, chemical vapor depositions (CVD), and electron cyclotron resonance-chemical vapor deposition (ECR-CVD), just to name a few, are used. In some of these processes, the power input to the wafer can be as much as 8 W/cm^2. As an example, for a 6-inch wafer, this is equivalent to a total power input of nearly 1500 watts. To maintain the wafer at the desired process temperature requires this amount of heat energy be removed from the wafer during the process. Thus, a substantial difference in temperature (ΔT) between the wafer and the chuck must be maintained in order to realize the required heat energy extraction from the wafer.

In a prior art system utilizing the circulation of cooling water, a considerable amount of cooling water flow must be maintained in order to dissipate the heat generated by such energy input. For example, an 1800 W energy input system would require approximately 0.5 liter/second (6.6 gallons/minute) flow of cooling water having a ΔT value of 1° C. from inlet to outlet. Thus, considerable amount of cooling water must be circulated in order to dissipate the required energy. Although it is possible to substitute other cooling fluids to reduce the required volume of flow of the coolant, significant amount of liquid is still needed and the liquid must be maintained in a closed system for recirculation. In many instances condensation or other processes for reclaiming the liquid is needed within the closed system.

Furthermore, with most prior art closed loop systems, fluid passages are typically present within the wafer chuck to circulate the cooling fluid in order to dissipate the heat from the chuck. Additionally, in a closed loop system, the temperature of the circulating fluid will typically need to be controlled. In some instances where an expansion chamber is used, such as in a system utilizing liquid gas which is expanded to remove the heat, a sophisticated closed loop system must be present in order to control the temperature of the chuck, as well as maintaining the proper flow of a specially designated coolant, other than water, to the wafer chuck.

In those special processes, such as plasma etch and ECR-CVD processes, additional temperature control problems are encountered. These processes deposit substantial amounts of energy into the wafer and the wafer must be cooled by the wafer chuck to keep it at the selected process temperature. For example, in one CVD-SiO_2 deposition process, the temperature of the chuck is controlled to a value in the range of 65° to 90° C. by circulating thermostated liquid through the base of the chuck. If a cold (room temperature) wafer is loaded onto the chuck, the wafer will be heated to the temperature of the chuck within a few seconds. The wafer temperature, however, is still 200° to 400° C. below the optimum deposition temperature. If the film deposition is begun before the wafer is at this temperature, the quality of the initial layer of the film will be inferior to that deposited at the optimum process temperature. Alternatively, with no silane flow into the reactor the plasma can be used to heat the wafer without deposition, but at the cost of an additional 15 to 20 seconds added to the process. For a 120 second process that represents an increase in process time of about 16% or a proportional decrease in yield in the number of wafers that can be processed per hour.

For maximum throughput of the tool in certain high energy processes, such as plasma processes, it is imperative that the wafer be brought up to its operating temperature as quickly as possible and once the operating temperature has been reached, to remove the process generated heat from the wafer in a controlled manner. In order to provide these objectives, it is preferred that a chuck be designed to accommodate the thermal shock of drastic temperature changes of the order of 200°

C./sec and yet maintain the ability to dissipate heat energy in order to control the temperature of the wafer. In such a design, it is preferable to design an economical, yet efficient system, to reach the desired objectives.

SUMMARY OF THE INVENTION

A wafer chuck which utilizes the latent heat of vaporization of water or other liquids to extract heat to cool the wafer is described. The chuck has a substantially flat upper surface for the placement of a semiconductor wafer, but the chuck is substantially hollow in the interior. At the lower portion of the chuck, spray mechanisms are positioned into the cavity for spraying liquid in the cavity. The nozzles spray a mist of liquid to the underside surface of the chuck having the wafer residing thereon. Upon contact the liquid vaporizes if the chuck temperature is greater than the boiling point of the liquid. Heat extraction from the wafer is enhanced by using the latent heat of vaporization of the liquid. The operating temperature of the chuck can be established by the selection of a liquid of suitable boiling point. A central exhaust opening is also provided at the lower portion of the chuck to remove vapor from the cavity. When water is used, the steam can be readily exhausted into the air. For other fluids, an external condenser can be used to recycle the fluid.

An insulated heater is provided on the upper surface of the chuck, disposed between the chuck and the wafer, in order to raise the temperature of the wafer to its operating range. Thus, the wafer can be rapidly brought up to its operating temperature, prior to the commencement of the wafer process cycle.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is pictorial view of a wafer chuck of the present invention.

FIG. 2 is a cross-sectional view of the wafer chuck of FIG. 1.

FIG. 3 is a drawing of the wafer chuck of the present invention, showing the placement of various inlet and exhaust openings.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A wafer chuck for using the vaporization of water to remove excess heat energy from a semiconductor wafer is described. In the following description, numerous specific details are set forth, such as specific shapes, materials, etc., in order to provide a thorough understanding of the present invention. It will be obvious, however, to one skilled in the art that the present invention may be practiced without these specific details. In other instances, well-known techniques have not been described in detail in order not to unnecessarily obscure the present invention.

The present invention provides for a wafer chuck which is to be utilized in processing wafers in a temperature range of −150° to +500° C. It is especially designed for use with processes where substantial energy input to the wafer is encountered, such as during plasma etch, CVD and ECR-CVD depositions, but not necessarily limited to these. Although the present invention is described in reference to its use in a plasma environment, it is to be noted that the present invention can be used in non-plasma environment as well.

In a typical plasma process a given semiconductor wafer is loaded into a chamber and onto a chuck which is most likely at or near room temperature. Then some form of heating means will be required to raise the temperature of the wafer to the desired operating point if it is above room temperature. Conversely, if the desired operating point is below room temperature, then some form of cooling means, typically that provided by a lower boiling point liquid, will lower the temperature of the wafer below room temperature.

Usually, the operating point falls within a temperature range of −150° to +500° C. Some finite amount of time is required to change the wafer temperature from room temperature to the operating temperature. If, in a plasma system, plasma is used to heat the wafer to raise it to the operating temperature, a significant portion of the total process time may be devoted to changing (raising the temperature in this instance) the temperature of the wafer to the desired operating temperature. For process efficiency it is desirable to reach this operating temperature in the minimum amount of time possible, so that critical processing time is not utilized in the preparation stage, but instead is used in the actual plasma processing stage for etching or depositing. However, once the operating temperature has been reached, the temperature of the wafer will continue to rise unless the chuck is capable of dissipating the process generated heat in order to maintain the wafer at a controllable operating temperature. Thus, for an efficient plasma processing operation, the wafer is brought to the operating temperature as rapidly as possible by electrical heating. Once the operating temperature has been reached, the plasma process is switched on, the electrical heater is switched off and the liquid spray is started to provide cooling of the chuck in order to maintain the wafer at the desired operating temperature. When water is used as the cooling liquid, a cooling rate of greater than 200° C./sec can be realized.

The wafer chuck of the present invention provides for rapid cooling to quickly change the chuck temperature to maintain the wafer at the desired operating temperature when the plasma is switched on in a plasma etching or deposition reactor chamber. Optionally, the chuck of the present invention provides a means for heating the chuck and the wafer by introducing heat energy by the use of an electrical heater to bring the wafer quickly up to its operating temperature. In order to provide for the desired rapid heating and/or the rapid cooling of the chuck, the chuck must be capable of withstanding the severe thermal shock (temperature change per unit time) that the chuck will necessarily undergo during the cooling and heating cycles. The wafer chuck of the present invention provides for these requirements.

Referring to FIGS. **1**, **2**, and **3**, a wafer chuck **11** of the present invention is shown. Chuck **11** is a three-dimensional disk which is circular in shape and substantially flat on its upper surface to accommodate a typical circular semiconductor wafer **20**. The interior of chuck **11** is substantially hollow, thereby forming a cavity **12** within. At the lower surface **18** of chuck **11**, a plurality of inlet openings **21** are disposed at various predetermined locations. Also along the bottom surface **18** of chuck **11**, an outlet opening **25** is located. In the preferred embodiment, outlet opening **25** is centrally disposed while inlet openings **21** are distributed concentrically and having equidistant separation. The actual number and position of the openings **21** are a design choice as long as the cooling constraints below are met. Furthermore, it is to be noted that although the present invention is described in terms of using water as the

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