

Inflatable Elastomeric Element for Rapid Thermal Processing (RTP) System

1. Field of the invention.

The present invention relates to an apparatus and method for sealing a large transparent quartz plate to the body of an RTP chamber using an inflatable O-ring to provide uniform pressure on the plate.

2. Background of the invention.

Rapid Thermal Processing (RTP) is a versatile optical heating method which can be used for semiconductor processing as well as a general, well controlled, method for heating objects or wafers which are in the form of thin sheets, slabs, or disks. The objects are generally inserted one at a time into a chamber which has at least some portions of the chamber walls transparent to transmit radiation from powerful heating lamps. The transparent portion of the walls is generally quartz, which will transmit radiation up to a wavelength of 3 to 4 microns. These lamps are generally tungsten-halogen lamps, but arc lamps or any other source of visible and/or near infrared radiation may be used. The radiation from the lamps is directed through the transparent portions of the walls on to the surface of the object to be heated. As long as the objects absorb light in the near infrared or visible spectral region transmitted by the transparent portion of the walls, RTP techniques allow fast changes in the temperature and process gas for the different material processes and conditions. RTP allows the „thermal budgets“ of the various semiconductor processing to be reduced, as well as allows the production of various metastable states which can be „frozen in“ when the material is cooled rapidly.

RTP systems are relatively new. In the last 10 or 15 years, such systems were used only in research and development. The thrust of the work was increasing the temperature uniformity, and developing heating cycles and processes which decreased the thermal

1 budget. Prior art RTP machines can heat unstructured, homogeneous materials in the form of a flat plate or disk, and produce temperature uniformities across the plate adequate for semiconductor processing processes.

5 The temperature control in current RTP systems is mostly performed by monochromatic (or narrow wavelength band) pyrometry measuring temperature of the relatively unstructured and featureless backside of semiconductor wafers. The results of the temperature measurement are generally used in a feedback control to control the heating lamp power. Backside coated wafers with varying emissivity can not be used in this
10 way, however, and the backside layers are normally etched away or the temperature is measured using contact thermocouples.

A newer method of temperature control is the power controlled open loop heating described in U.S. Patent No. 5,359,693, which patent is hereby incorporated by
15 reference.

German patent DE 42 23 133 C2, hereby incorporated by reference, discloses a method of producing relatively defect free material in RTP machines. Apparatus induced thermal inhomogeneities have been reduced in the last few years because of the demand
20 for more uniform processing. Among the techniques used have been control of the individual lamp power, use of circular lamps, and rotation of the semiconductor wafers with independent power control.

Most RTP machines have a thin rectangular quartz reaction chamber having one end
25 open. The reaction chamber is made from a set of flat quartz plates joined together ("welded") in a manner known in the art. Chambers meant for vacuum use often have a flattened oval cross section. Chambers could even be made in the form of a flat cylindrical pancake. In general, the chambers are used so that the thin objects to be
30 heated are held horizontally, but they could also be held vertical or in any convenient orientation. The reactor chamber is usually thin to bring the lamps close to the object to be heated. The reactor chamber is opened and closed at one end with a pneumatically operated door when the wafer handling system is in operation. The door is usually made
35 of stainless steel, and may have a quartz plate attached to the inside. The process gas is introduced into the chamber on the side opposite the door and exhausted on the door

1 side. The process gas flow is controlled by computer controlled valves connected to various manifolds in a manner well known in the art.

As wafer sizes increase to 300 mm diameter, the quartz "boxes" are increasingly
5 expensive to produce and to use. The amount and size of ancillary equipment inside the RTP chamber is increasing at the same rate. RTP chambers made from different materials, however, have difficulties in that the hot wafers radiate long wavelength
10 infrared radiation, which heats the quartz walls of the RTP systems which are transparent only to visible and near infrared light. It is thus difficult to seal the transparent walls of the system to the differing material of the non transparent walls, because the differential expansion of the different materials leads to relative motion of the various parts of the RTP chamber. The differential expansion leads to very non
15 uniform forces at different portions of the quartz plates, and such forces can crack the very expensive plates.

Relative motion between the quartz plates and the other parts of the RTP chamber can
"scrub" the sealing material and cause contamination of chamber. This contamination is particularly bad for chemical vapor deposition (CVD) of silicon-germanium, where the
20 system must be extraordinarily clean and where the entire system must be "baked" to remove all traces of water vapor from the walls of the system, and where normal sealing materials outgas sufficient material to prevent good CVD growth. Metal gaskets must be used and must be compressed with high pressures, and upon non uniform heating of the
25 quartz plates, the plates may crack.

3. Related Applications.

30 Reactors based on the RTP principle often have the entire cross section of one end of the reactor chamber open during the wafer handling process. This construction has been established because the various wafer holders, guard rings, and gas distribution plates, which have significantly greater dimensions and may be thicker than the wafers, must
35 also be introduced into the chamber and must be easily and quickly changed when the process is changed or when different wafer sizes, for example, are used. The reaction

1 chamber dimensions are designed with these ancillary pieces in mind. US Patent
5,580,830, assigned to the assignee of the present invention, and hereby incorporated by
reference, teaches the importance of the gas flow and the use of an aperture in the door
5 to regulate gas flow and control impurities in the process chamber.

The wafer to be heated in a conventional RTP system typically rests on a plurality of
quartz pins which hold the wafer accurately parallel to the reflector walls of the system.
Prior art systems have rested the wafer on an instrumented susceptor, typically a
10 uniform silicon wafer.

Copending patent application 08/537,409, assigned to the assignee of the present
invention, hereby incorporated by reference, teaches the importance susceptor plates
separated from the wafer.

15 Rapid thermal processing of III-IV semiconductors has not been as successful as RTP of
silicon. One reason for this is that the surface has a relatively high vapor pressure of, for
example, arsenic (As) in the case of gallium arsenide (GaAs). The surface region
becomes depleted of As, and the material quality suffers. Copending patent application
08/631,265, assigned to the assignee of the present invention, hereby incorporated by
20 reference, supplies a method and apparatus for overcoming this problem.

OBJECTS OF THE INVENTION

25 It is an object of the invention to produce an RTP system which is clean and gas tight,
and which will remain clean and gas tight after many cycles of heating and cooling of
the chamber. It is an object of the invention to produce an RTP chamber which may be
rapidly and easily disassembled for cleaning and for loading of ancillary equipment into
the chamber. It is an object of the invention to produce an RTP chamber which can be
30 cleaned to ultrahigh vacuum standards of cleanliness.

SUMMARY OF THE INVENTION

The quartz plate window of a processing chamber of an RTP system is sealed to the body of the chamber using an inflatable elastic element which presses uniformly on the window regardless of the relative motion of the window and the body as the window and the body heat up and cool down during the rapid thermal cycles of the RTP system.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a sketch of a prior art open ended quartz reactor chamber RTP system with two banks of heating lamps.

Fig. 2 is a sketch of the RTP chamber of the most preferred embodiment of the invention.

Fig. 3 is a sketch of the RTP chamber of a preferred embodiment of the invention.

Fig. 4 is an expanded sketch of region A of fig. 2.

Fig. 5 is an expanded sketch of a region of fig. 3.

Fig. 6 is an expanded sketch of a preferred embodiment of the invention.

Fig. 7 is an expanded sketch of a preferred embodiment of the invention.

Fig. 8 is an expanded sketch of a preferred embodiment of the invention.

Fig. 9 is an expanded sketch of a preferred embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

Fig. 1 shows a cross sectional sketch of a prior art RTP chamber 10 with a wafer 12 supported by quartz pins 14 in position for heating by radiation from a set of lamps 16 and 18. The chamber 10 is supported by a housing 20 having highly polished interior walls 22. A door 24 is used to make a gas tight seal for the chamber 10. The temperature of the wafer 10 is measured by a pyrometer 26. A computer or other control means 28 receives the temperature reading from the pyrometer 26, and controls the lamps 16 and 18 to heat the wafer 12 according to a preprogrammed schedule. The computer 28 also serves to control a gas flow controller 30 which introduces process gas 28 into the chamber 10.

1 Fig. 2 shows the most preferred embodiment of the invention. The wafer 10 is held in
position for processing by quartz pins (not shown). One set of lamps 16 is shown. The
RTP chamber depicted in fig. 2 comprises a body 30 and at least one plate 32 which is
5 transparent to the radiation from the lamps 16 or other radiation sources as are known in
the art of RTP. The body 30 of the chamber is preferably made from a metal such as
aluminum or stainless steel. An opening (not shown) is machined in the body for
inserting the wafer 10. A door (not shown) may be used for sealing this opening to
10 retain process gases inside the chamber when the wafer 12 is being heated. The gas
supply to the chamber is not shown. The gas supply system and the gas control system
is well known in the art. The body 30 may be a hollow cylinder or a hollow rectangular
shape.

15 The plates 32 and 32 are preferably made of quartz, which is substantially transparent to
most of the radiation from the lamps 16. However, the quartz absorbs radiation with
wavelengths longer than approximately 4 microns. When the wafer is hot, the wafer
radiates energy in the far infrared having wavelengths longer than 4 microns, and such
radiation is absorbed very readily in the quartz plate 32. The body 30 of the chamber
20 may be readily water cooled, and the plate 32 cooled by air flow, but the differential
temperatures between the body 30 and the plate 32, and the temperature differences over
the plate 32, give rise to relative motion of the body 30 and the plate 32. Typical sealing
methods using o-ring seals and bolting the plate 32 against the body 30 often result in
25 cracking of the quartz plate. It has been found that an inflatable member 34 such as an
inflatable O-ring may be used as shown in Fig. 2 to apply steady pressure against the
plate 32 when the inflatable elastic member is inflated. A ring 35 with an O-ring groove
is shown for holding the inflatable O-ring 34 in place. A sealing element 36 may then be
30 used to prevent gas flow between the body 30 and the plate 32 of the RTP chamber
when the sealing is activated by inflating the inflatable element 34 to press the plate 32
against the sealing element 36. The sealing element 36 may be a elastomeric O-ring.
The most preferable sealing element 36 is made from a fully fluorinated material such as
35 Teflon (TM). Typical viton O-rings may be scrubbed by the relative motion of plate 32
and body 30, and contaminate the chamber and the wafer 12. In addition, the heat

1 conducted from the center of the plate 32 to the outside of the plate can be transferred to
the sealing element 36 and raise the temperature of the sealing element 36 to a point
where it degrades and causes contamination. The use of a Teflon (TM) sealing element
5 avoids both of these problems. The encircled area A shown in Fig. 2 shows an area of
the drawing which will be shown in expanded form in later figures for the some of the
various embodiments anticipated by the inventors.

The inflatable element 34 may be and inflatable elastomeric element, or it may be a
10 metallic bellows arrangement to give the needed elasticity.

Fig. 3 shows an alternative preferred embodiment of the invention, where the inflatable
element 34 is stretched around the perimeter of a circular quartz plate 32. The relative
motion of the plate 32 and the body 30 in this case compress the inflatable O-ring and
does not lead to scrubbing of the surface of the inflatable O-ring. In the embodiment
15 depicted in Fig. 3, the inflatable element itself seals the plate 32 to the body 30 when the
inflatable element 34 is inflated. There are many cross sections for the inflatable
element 34 which may be used in the embodiment sketched in fig. 3 and other
embodiments. The lines for the fluid used to inflate the inflatable element 34 are not
20 shown in these sketches.

Fig. 4 shows an expanded sketch of the area A of Fig. 2 Fig. 5 shows a sketch of the
corresponding portion of Fig. 3. Fig. 6 shows a corresponding area for a system where
the inflatable elastomeric element 34 of fig. 2 is protected by a thin sheet 40 of Teflon
25 (TM) from sticking to the plate 32 when the temperature of plate 32 rises. Also shown
in fig. 6 is a plate 32 made with the addition of "opaque" quartz 42 around the central
area of plate 32. The opaque quartz 42 has many small vacuum filled voids which
scatter the visible light from the lamps 16, and prevent the visible and near IR light from
being "light piped" to the element 34 and which cut down on the heat thermally
30 conducted from the center of the plate 32 to the perimeter of the plate 32.

Fig. 7 shows a sketch of an inflatable O-ring 34 which is used to both seal and to apply
the needed pressure to seal the body 30 to the plate 32.

35 Fig. 8 shows the sealing element to be a soft copper gasket or seal 44 known in the art
of ultra-high vacuum. Such a seal is necessary when utmost purity is needed in the

1 chamber for work with, for example, Si-Ge CVD. An alternative and more preferred
sealing element for such ultrahigh purity work is shown in Fig. 9, where a metal coated
elastic element 46 is shown as the sealing element.

5 While the foregoing specification deals with single element quartz or other transparent
plates, it is anticipated by the inventors that transparent plates joined with metal in a
manner known in the art may also be sealing in the manner shown above.

10 The authors anticipate that many different kinds of inflatable elastic elements may be
used to activate the sealing of an RTP chamber. In particular, it may be that higher
temperature materials may be used or invented for such a use, and that particular shapes
may be well suited for particular processes. The use of such new materials and different
shapes will become obvious to one skilled in the art as a result of this disclosure.

1 We claim:

5 1. A rapid thermal processing (RTP) chamber, comprising;

a body, and



10 at least one plate held in close proximity to the body, at least a portion of the plate transparent to radiation from radiation sources of an RTP system, the plate forming a gas tight seal to the body, the gas tight seal activated by an inflatable element.

15 2. The apparatus of claim 1, wherein a sealing element is placed between the body and the plate, and wherein the inflatable element presses the plate and the body relatively together when the inflatable element is inflated.

20 3. The apparatus of claim 2, where an inert, high temperature resisting material is placed between the inflatable element and the plate.

25 4. The apparatus of claim 3, where the inert, high temperature resisting material is Teflon (TM).

5. The apparatus of claim 2, where the sealing element is a Teflon (TM) sealing element.

30 6. The apparatus of claim 2, where the sealing element is a copper gasket ultrahigh vacuum sealing element.

35 7. The apparatus of claim 2, where the sealing element is a metal covered elastomeric sealing element.



- 1 8. The apparatus of claim 1, wherein the inflatable element is located between the
plate and the body.
- 5 9. The apparatus of claim 1, wherein the plate is a circular plate having a perimeter,
and the inflatable element is located around the perimeter of the plate.
- 10 10. The apparatus of claim 1, wherein the plate is a quartz plate having a region near
the perimeter of the plate which scatters the radiation.
- 15 11. A rapid thermal processing (RTP) system, comprising;

a source of radiation;

an RTP chamber comprising a body and at least one plate held in close
proximity to the body, at least a portion of the plate transparent to radiation from
the radiation source, the plate forming a gas tight seal to the body, the gas tight
20 seal activated by an inflatable element;

a gas control means for introducing a gas into the RTP chamber; and

25 a means of controlling the source of radiation to heat an object contained in the
RTP chamber and a means of controlling the gas control means to surround the
object with a suitable gas when the object is being heated.
- 30 12. The system of claim 10, wherein a sealing element is placed between the body
and the plate, and wherein the inflatable element presses the plate and the body
relatively together when the inflatable element is inflated.
- 35 13. The system of claim 11, where an inert, high temperature resisting material is
placed between the inflatable element and the plate.

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14. The system of claim 12, where the inert, high temperature resisting material is Teflon (TM).

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15. The system of claim 11, where the sealing element is a Teflon (TM) sealing element.

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16. A method of rapid thermal processing (RTP) of an object using an RTP system, comprising;

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placing the object in an RTP chamber, the RTP chamber having a body and at least one plate held in close proximity to the body, at least a portion of the plate transparent to radiation from radiation sources of the RTP system, the plate forming a gas tight seal to the body, the gas tight seal activated by an inflatable element; and

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heating the object with radiation from the radiation source.



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17. The method of claim 15, wherein a sealing element is placed between the body and the plate, and wherein the inflatable element presses the plate and the body relatively together when the inflatable element is inflated.

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18. The method of claim 16, where an inert, high temperature resisting material is placed between the inflatable element and the plate.

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19. The method of claim 17, where the inert, high temperature resisting material is Teflon (TM).

20. The method of claim 16, where the sealing element is a Teflon (TM) sealing element.