

CRYOPUMP

FIELD OF THE INVENTION

The field of the invention relates to cryopumps.

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BACKGROUND

Cryopumps and in particular two stage cryopumps are configured to provide high vacuums by capturing type I gases such as water vapour at a first stage temperature and type II gases such as nitrogen at a second stage temperature.

10 In some cases they are further configured to cryoadsorb type III gases such as hydrogen.

Where such cryopumps are used to evacuate semiconductor process chambers then it is important that they can store large quantities of type II gasses and are
15 able to recover the chamber pressure between wafers. The longer a pump can perform (store gasses and recover pressure) without needing to be regenerated the more valuable the pump is for its user. The inside volume of a cryopump, the frost temperature and shielding along with how efficiently the frost is formed dictates the amount of gas that can be stored.

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Conventional cryopumps have used the same vessel size and internal volume from the 10 or 11K top plate to the 100K sputter plate for many years. Such cryopumps conventionally have an have an 8" (20cm) internal diameter frontal opening that corresponds to the opening in the process chamber being
25 evacuated. Over that span of time pumping performance requirements have grown as new processes emerge and longer time between regeneration of the cryopumps are expected. Enhancements have been made to the existing array designs and shielding to increase the capacity of the pump and its vacuum stability.

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It would be desirable to further increase the capacity of a cryopump to capture type II gasses and thereby extend the capacity and time between regenerations of such a pump.

5 SUMMARY

A first aspect provides a cryopump comprising: a vessel comprising a radiation shield having a frontal opening, said frontal opening forming an inlet to said vessel; a frontal array thermally coupled to said radiation shield and mounted across said frontal opening; a cryopanel structure mounted within said vessel; a
10 two stage refrigerator extending into said vessel, a first stage of said refrigerator being thermally coupled to said radiation shield and a colder second stage of said refrigerator being thermally coupled to said cryopanel structure; wherein said vessel comprises an elongate vessel a distance between a surface of said cryopanel structure closest to said frontal opening and a surface of said frontal
15 array closest to said cryopanel structure comprising between 0.6 and 1.2 times the diameter of said frontal opening.

As noted above cryopumps are often used to generate and maintain a vacuum in a semiconductor processing chamber such as in physical vapour deposition
20 processes. In such processing it is important that the vacuum is maintained to a high vacuum level, and that where a wafer is exchanged, this high vacuum is achieved again quickly. Cryopumps are capture pumps and thus, they need periodically to be regenerated. Regeneration of a pump means that during this process the processing chamber cannot be used and thus, it is advantageous if
25 the frequency of the regeneration can be reduced.

The frequency of regeneration is related to the capacity of the pump and the amount of gas molecules that can be captured before the operation of the pump deteriorates. Gas molecules may be captured as frost on the cryopanel and this
30 frost grows up towards the frontal opening. There is a temperature gradient across the length of the frost as it grows and where the frost gets too warm then gas molecules start to escape and this reduces the effectiveness of the pump.

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Furthermore, where a cryopump is used in the semiconductor processing industry, it is designed to fit into the confined space associated with a semiconductor processing fab and thus, there is a desire to provide a compact pump.

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Conventionally cryopumps have been configured to have a frontal opening of 8 inches (20.3 cm) which corresponds to the opening of a semiconductor processing chamber. They are also configured with a length from the base to the frontal opening of about 1.2 times the size of the diameter, that is 24.6 cm (9.7
10 inches) and a length from the upper surface of the cryopanel structure to the lower surface of the frontal array of less than half the diameter of the frontal opening, around 3.8 inches (9.6cm).

The inventor found that by elongating the vessel, and in particular increasing the
15 distance between the cryopanel structure and the frontal array, the capacity of the cryopump and in particular the region where frost is stored is increased and yet the capture of the molecules remains effective. Elongating the vessel by increasing this dimension provides additional space in the portion of the vessel that stores the "frost" or captured type II gases. Furthermore, lengthening the
20 distance between the cryopanel structure and the frontal array allows the cryopanel structure to be more remote from the frontal opening and as the frontal opening is a source of radiation this allows the cryopanel structure to maintain a lower temperature and thus, provides improved retention of the frost.

25 In some embodiments, said distance is between 0.7 and 0.9 times the diameter of said frontal opening.

In other embodiments the distance is between 0.8 and 1.1 times the diameter of the frontal opening.

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Although the optimal increase in length does depend on circumstances, the configuration of the pump, including the temperature of the second stage

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cryopanel and the effectiveness of the radiation shields, and also in some cases on the proposed use of the pump, it has been found in many circumstances that elongating the vessel such that the distance between the cryopanel structure and the frontal array is between 0.7 and 0.9 times the diameter of said frontal opening provides a particularly effective increase in storage capacity without unduly degrading the capture stability of the gas.

In some embodiments, the diameter of the frontal opening is between 20 and 21 cm (7.8 and 8.2 inches) and the distance between said cryopanel structure and said frontal array is between 12 cm and 25cm (4.7 and 10 inches).

In some embodiments, said second stage of said two stage refrigerator is configured to maintain a temperature of said cryopanel to below 9K.

As noted above the storage capacity of a cryopump may be increased by increasing the volume available to store the frost. However, as the frost grows towards the frontal opening, there is a temperature gradient across the frost and elongating this distance makes maintaining the portion of the frost closest to the frontal opening at a low temperature increasingly difficult. When the frost reaches a certain temperature then gas molecules will start to escape and the efficacy of the pump will deteriorate. Providing a cryopanel structure of a lower temperature enables the frost length to increase, while the temperature of the surface remote from the cryopanel remains low enough to securely hold the gas molecules.

In some embodiments, said frontal array comprises a disk element and an annular element, said disk element and said annular element being mounted axially displaced from each other said annular element being mounted to be closer to said frontal opening than said disk element, a diameter of said disk element being equal to or greater than a diameter of the aperture in said annular element and smaller than an outer diameter of said annular element, said outer

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diameter of said annular element being equal to or greater than a diameter of said frontal opening.

5 A further way of maintaining a low temperature within the vessel and protecting the increased volume of frost from radiation is to improve the effectiveness of the frontal array. Providing a frontal array with longitudinally displaced elements allows the channels into the vessel to be in the axial plane and not the radial plane. This avoids or at least impedes any line of sight channels into the vessel and thereby protects the vessel from external radiation, allowing the upper
10 surface of the frost to maintain a lower temperature.

In some embodiments, said frontal array comprises a further axially extending cylindrically-shaped element, said cylindrically-shaped element connecting said disk element and annular element, said cylindrically-shaped element comprising
15 a cylindrical surface, said cylindrical surface comprising a plurality of apertures.

A further aspect provides a cryopump comprising: a vessel comprising a radiation shield having a frontal opening, said frontal opening forming an inlet to said vessel; a frontal array thermally coupled to said radiation shield and mounted
20 across said frontal opening; a cryopanel structure mounted within said vessel; a two stage refrigerator extending into said vessel, a first stage of said refrigerator being thermally coupled to said radiation shield and a colder second stage of said refrigerator being thermally coupled to said cryopanel structure, said second stage of said refrigerator being configured to maintain a temperature of said
25 cryopanel structure to below below 9K.

A yet further aspect provides a cryopump comprising: a vessel comprising a radiation shield having a frontal opening, said frontal opening forming an inlet to said vessel; a frontal array thermally coupled to said radiation shield and
30 mounted across said frontal opening; a cryopanel structure mounted within said vessel; a two stage refrigerator extending into said vessel, a first stage of said refrigerator being thermally coupled to said radiation shield and a colder second

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- stage of said refrigerator being thermally coupled to said cryopanel structure;
wherein said frontal array comprises a disk element and an annular element, said
disk element and said annular element being mounted axially displaced from
each other said annular element being mounted to be closer to said frontal
5 opening than said disk element, a diameter of said disk element being equal to or
greater than a diameter of the aperture in said annular element and smaller than
an outer diameter of said annular element, said outer diameter of said annular
element being equal to or greater than a diameter of said frontal opening.
- 10 In some embodiments, said frontal array comprises an axially extending
cylindrically-shaped element, said cylindrically-shaped element connecting said
disk element and annular element said cylindrically-shaped element comprising a
cylindrical surface, said cylindrical surface comprising a plurality of apertures.
- 15 Further particular and preferred aspects are set out in the accompanying
independent and dependent claims. Features of the dependent claims may be
combined with features of the independent claims as appropriate, and in
combinations other than those explicitly set out in the claims.
- 20 Where an apparatus feature is described as being operable to provide a function,
it will be appreciated that this includes an apparatus feature which provides that
function or which is adapted or configured to provide that function.

BRIEF DESCRIPTION OF THE DRAWINGS

- 25 Embodiments of the present invention will now be described further, with
reference to the accompanying drawings, in which:
Figure 1 schematically shows the difference between a conventional cryopump
and one according to an embodiment; and
Figure 2 schematically shows the frontal array according to an embodiment.

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DESCRIPTION OF THE EMBODIMENTS

Before discussing the embodiments in any more detail, first an overview will be provided.

5 Cryopumps and in particular, PVD (physical vapour deposition) process cryopumps store large quantities of type II gasses and are required to recover the chamber pressure between wafers. The longer a pump can perform (store gasses and recover pressure) without needing to be regenerated the more valuable the pump is for its user. Enhancements have been made to the
10 conventional array designs and shielding to increase the capacity of the pump and its vacuum stability. These improvements have enabled the usable physical volume available for frost within the pump below the sputter plate to be enhanced. Although these enhancements have had some success in helping to better utilize the volume available to store the gasses they have not been able to
15 significantly increase the litres of gas it can store. To further increase the volume of a pump with a conventional flange size, it is proposed to elongate the pump such that an extra volumetric capacity further from the frontal opening is provided. In some embodiments, to further improve gas storage capacity better radiation shielding is provided and/or a lower temperature second stage
20 cryopanel.

In effect, the inside volume of a cryopump, the frost temperature and shielding plus how efficiently the frost is formed dictates the amount of gas that can be stored. If the pump's useful gas volume is increased by lengthening the vessel
25 and cylindrical radiation shield then the capacity may be increased. In particular, if the lengthening is performed in conjunction with an improved shielded sputter plate and/or with a refrigerator unit with lower 2nd stage temperature then an increased storage capacity of up to 50% is possible. Increasing the volume of the cryopump is important to allow a significant increase in its capacity for storing
30 type II gasses. To conclude an elongated cryopump improves capacity, and does so particularly effectively when configured with better shielding and/or lower 2nd stage cryopanel temperatures.

Figure 1 schematically shows a comparison between a conventional cryopump on the left and a cryopump according to an embodiment on the right. The cryopump according to an embodiment has an elongated vessel 10 when compared to the conventional pump while still utilizing the same vessel flange size. In some embodiments the length of the vessel is increased by between 1 to 6 inches (2.5 to 15cm). The portion of the vessel that is elongated is the portion surrounded by the radiation shield 12 and is the portion between the cryopanel structure 30 and the frontal array 20. Increasing this length increases the volume available for storing type II gas as frost. It also increases the frost's distance from the very cold cryopanel surfaces ~ 10K to the 100K sputter plate. In this way the distance 40 between the upper surface of the cryopanel structure 30 and the lower surface of the frontal array is lengthened and the volume A available to store frost is increased.

In the conventional cryopump shown schematically and not to scale in the left-hand figure the distance between the cryopanel structure and the frontal array is about half the diameter 42 of the frontal opening. In embodiments the vessel is elongated so that this distance is increased to about 0.6 to 1.2 times the diameter, preferably between 0.7 and 0.9 times.

The cryopump comprises a radiation shield 12 that surrounds the region A where frost is stored. The radiation shield extends above the flange 15 by between 0.6 and 1" (1.5 to 2.5 cm) to isolate the cryopump from the vacuum vessel.

The capacity to capture gas and still recover pressure afterwards of the cryopump according to the embodiment is increased by making the vessel 10 and radiation shield 12 longer with more length/volume inside radiation shield 12. In this embodiment the cryopump also has an improved frontal array plate 20 across the frontal opening 22.

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The cryopump also has a reduced temperature of the second stage refrigerator that cools the cryopanel structure 30. This reduced temperature helps lower the frost temperature at the cryopanel structure and correspondingly along the frost cylinder and thereby compensates to some extent the effect of the increased frost
5 length on the upper surface temperature of the frost.

Allowing the frost to grow and form a longer cylinder makes keeping the upper surface of the frost at a low enough temperature to inhibit gas molecules escaping more difficult. Decreasing the inlet radiant heat load by improving the
10 shielding performed by the frontal array and/ or decreasing the temperature of the cryopanel structure and thus, the temperature of the base of the frost cylinder may each help in keeping the temperature of the upper surface of the frost cylinder at a lower temperature. Where the refrigerator's 2nd stage temperature is lowered below 10K preferably below 9K then this helps avoid or at least reduce
15 the escape of gas molecules.

A conventional frontal array plate 50 with holes in the form of louvers blocks most radiation but still allows some line of sight preferential pumping to occur. When the gas is being pumped it forms a crystal-like vertical structure that looks to be
20 more like threads than an accumulation of frost layered horizontally. These crystal "rods" start growth on the cold ~10K cryopanel like millions of threads attached to the cryopanel and stretching up to the 100K sputter plate or anything not at or below ~25K. Type II gas also pumps below the 10K cryopanel and forms on the lower panels and charcoal arrays but in limited quantities.

25 Increasing the length of the available volume for gasses to accumulate, decreasing the 2nd stage cryopanel temperature, and allowing less radiation/preferential pumping of gasses will increase the volume that can be stored. Furthermore, doing so by elongating the vessel is less expensive that
30 would be the case were a larger vessel with a larger flange size manufactured, it is also easily manufactured.

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The length of the extension may be from 1" up to 6" (2.5 to 15cm).

The shielding by the improved frontal array and/or the lower 2nd stage temperature although particularly useful in this embodiment are also applicable
5 for use in other cryopumps.

Figure 2 shows the frontal arrays of the conventional cryopump and that of an embodiment in more detail. The left hand figure shows the conventional frontal array 50 and the right hand figure a frontal array sputter plate 22 according to an
10 embodiment, when viewed from above (left-hand side) and below (right hand side). As can be seen there is an upper plate 20a that has a disk form, and a lower annular plate 20b. The disk has a larger diameter than the diameter of the opening in the annular plate 20b. There is a cylindrical element 20c with apertures 21 between the upper disc plate 20a and the inner diameter of the
15 lower annular plate 20b. These apertures are in the axially extending wall and in this way there is no direct line of sight between the interior and the exterior of the vessel, providing effective shielding of the frost within the vessel from radiation.

Although illustrative embodiments of the invention have been disclosed in detail
20 herein, with reference to the accompanying drawings, it is understood that the invention is not limited to the precise embodiment and that various changes and modifications can be effected therein by one skilled in the art without departing from the scope of the invention as defined by the appended claims and their equivalents.

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REFERENCE SIGNS

	10	cryopump vessel
	12	radiation shield
	15	flange
5	20	frontal array
	20a	upper disk plate
	20b	annular plate
	20c	cylindrical element
	21	apertures
10	22	frontal opening
	30	cryopanel structure
	40	length between cryopanel structure and frontal array
	42	diameter of frontal opening
	50	conventional frontal array
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CLAIMS

1. A cryopump comprising:
 - a vessel comprising a radiation shield having a frontal opening, said frontal
 - 5 opening forming an inlet to said vessel;
 - a frontal array thermally coupled to said radiation shield and mounted
 - across said frontal opening;
 - a cryopanel structure mounted within said vessel;
 - a two stage refrigerator extending into said vessel, a first stage of said
 - 10 refrigerator being thermally coupled to said radiation shield and a colder second
 - stage of said refrigerator being thermally coupled to said cryopanel structure;
 - wherein
 - said vessel comprises an elongate vessel a distance between a surface of
 - said cryopanel structure closest to said frontal opening and a surface of said
 - 15 frontal array closest to said cryopanel structure comprising between 0.6 and 1.2
 - times the diameter of said frontal opening.
2. A cryopump according to claim 1, wherein said distance is between 0.7
- and 0.9 times the diameter of said frontal opening.
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3. A cryopump according to any preceding claim, wherein the diameter of the
- frontal opening is between 20 and 21 cm (7.8 and 8.2 inches) and said distance
- between said cryopanel structure and said frontal array is between 12 cm and
- 25cm (4.7 and 10 inches).
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4. A cryopump according to any preceding claim, wherein said second stage
- of said two stage refrigerator is configured to maintain a temperature of said
- cryopanels to below 9K.
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5. A cryopump according to any preceding claim, wherein said frontal array
- comprises a disk element and an annular element, said disk element and said
- annular element being mounted axially displaced from each other said annular

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element being mounted to be closer to said frontal opening than said disk
element, a diameter of said disk element being equal to or greater than a
diameter of the aperture in said annular element and smaller than an outer
diameter of said annular element, said outer diameter of said annular element
5 being equal to or greater than a diameter of said frontal opening.

6. A cryopump according to claim 5, wherein said frontal array comprises an
axially extending cylindrically-shaped element, said cylindrically-shaped element
connecting said disk element and annular element, said cylindrically-shaped
10 element comprising a cylindrical surface, said cylindrical surface comprising a
plurality of apertures.