

CRYOPUMPS AND INLET FLOW RESTRICTORS FOR CRYOPUMPS

FIELD OF THE INVENTION

The field of the invention relates to cryopumps and to an inlet flow restrictor for
5 cryopumps.

BACKGROUND

Flow restrictors or throttle plates may be used to restrict the flow of gas into a
cryopump in order to limit the pumping speed of the pump and maintain a desired
10 pressure in the process chamber in for example PVD physical vapour deposition
processes. These flow restrictor plates have conventionally been provided with
multiple orifices of different geometric shapes through which type II and type III
gases enter the pump and whose size and number control the flow rate or speed.
A potential problem with plates having holes or orifices is that during viscous or
15 continuous flow the orifices have a line of sight view of the second stage
cryopanel in the pump and this increases radiant heat loads and can cause
preferential gas pumping at these sites. Preferential gas pumping can cause
columns of gas molecules condensed as "frost" to grow from the second stage
cryopanel up towards the plate openings particularly during high gas flow rates.
20 As the columns become more distant from the cryopanel they become warmer,
receive an increased radiant load and may start outgassing thus raising the
pressure in the chamber. Increased second stage temperature due to the radiant
loads and/or warmer gas columns cause the vapour pressure of the type II gases
to rise and pressure in the pump/chamber to rise with it. Type II gases are gases
25 such as nitrogen that condense at the temperatures of the second stage
cryopanel of a cryopump, while type III gases do not condense at these
temperature and are generally captured by an adsorbent on the cryopanel.

Figure 1 shows an example of a cryopump having a throttle or flow restrictor plate
30 5 according to the prior art. Flow restrictor plate 5 sits across the inlet of the
pump and comprises a plurality of orifices 7 through which gas flows into the
pump. The size of the orifices is selected for the desired pumping speed of the

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5 pump. The pump is a cryopump and has a refrigerator unit 15 with a first refrigerator heat station 10 connected to the inner housing of the pump which is insulated from the outer housing of the vacuum vessel 9. It also has a second stage heat station 11 which connects to second stage cryopanel 12 and other adsorbent cryopanels 13. The upper cryopanel 12 will experience frost build-up 14 over upper surface of the cryopanel with particular build-up forming spires at locations corresponding to orifices 7. A potential problem with the non uniform build-up of frost and with radiant heat loads is that the pressure recovery inside the chamber takes longer and regeneration may be required sooner.

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It would be desirable to provide a cryopump where the time between regenerations is increased and where pressure recovery times inside the chamber are decreased.

15 SUMMARY

A first aspect provides a flow restrictor for restricting a flow rate of gas flowing into a cryopump, said flow restrictor being configured to be mounted in an inlet of said cryopump, said flow restrictor comprising: an inlet component for providing a gas flow path into said cryopump; a shielding plate mounted to at least partially obscure said gas flow path through said inlet component; and an intermediate component linking said shielding plate to said inlet component, said intermediate component comprising at least one aperture, said at least one aperture defining at least one gas flow path into said cryopump; wherein said shielding plate is configured to shield said gas flow path through said inlet component such that 20 when mounted on said cryopump there is not a direct line of sight path through said inlet component to a cryopanel within said cryopump.

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In some embodiments the inlet component lies in a plane parallel to and offset from said shielding plate, such that when mounted on said cryopump said inlet component lies between said pumping chamber of said cryopump and said 30 shielding plate.

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The inventor recognised the problems associated with a conventional flow restrictor plate mounted on the inlet of a cryopump and addressed these problems by providing a two stage flow restrictor having an inlet component that is axially displaced from a shielding plate. The shielding plate shields the inlet
5 component from gases entering the pump through the inlet forcing the gases around the shielding plate and via an intermediate component to the gas flow path through the inlet component. Thus, gases entering the cryopump are diverted around the shielding component through the at least one aperture in the intermediate component and into the flow path through the inlet component. In
10 this way, direct line of sight of the inlet is shielded from the cyropanels by the shielding element and the preferential pumping paths provided by orifices that look directly at the cyropanels are avoided.

In some embodiments, said inlet component has an annular form delimiting an
15 orifice, said orifice defining said gas flow path. An annular form of the inlet component forming a single orifice provides for more uniform flow across the cross sectional area of the inlet and helps inhibit preferential build-up of frost on the cyropanels at particular sites.

20 In some embodiments, said intermediate component comprises a plurality of apertures.

The intermediate component may be provided with a single aperture running around the surface linking the shielding plate and inlet component or it may have
25 multiple apertures. The size of the apertures and/or the number of apertures may be selected to limit the flow to a desired amount depending on the requirements of the cryopump. Where there are multiple apertures selecting both the size and number of apertures may allow for accurate control of flow rates.

30 In some embodiments, a surface of said intermediate component comprising said at least one aperture lies at an angle of between 120° and 60° to said shielding plate.

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It is advantageous if the intermediate component is angled with respect to the shielding plate and the inlet component such that the apertures do not look directly at the cyropanels. In this regard, may be advantageous if it is at an angle
5 of between 60° and 120° to the plane of the shielding plate and in some embodiments if it is substantially perpendicular to the shielding plate.

In some embodiments, said intermediate component comprises a cylinder.

10 In some embodiments, an outer periphery of said inlet component extends beyond an outer periphery of said shielding plate.

An advantageous geometry of the shielding plate and the inlet component may be for the shielding plate not to extend as far as the outer perimeter of the inlet
15 component but to extend further than the outer perimeter of the orifice of the inlet component. In this way, the orifice is directly shielded by the shielding plate but a path for gas to enter the pump around the edge of the shielding plate and then through the intermediate component is provided.

20 Although the geometry of the shielding plate and inlet component may have a number of forms such as rectangular, square or oval, in some embodiments, said shielding plate and said inner component have a substantially circular outer perimeter.

25 A circular cross section for a cryopump is generally advantageous for more uniform flow.

In some embodiments, said at least one aperture of said intermediate component is configured to restrict flow into said cryopump to a predetermined flow rate.

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The size and/or number of the aperture(s) of the intermediate component may be selected according to the desired flow rate of the process being performed in the chamber evacuated by the cryopump.

- 5 A second aspect provides a cryopump comprising: a pump inlet; a refrigeration unit; a cryopanel configured to be cooled by said refrigeration unit; and comprising a flow restrictor according to a first aspect, said flow restrictor being mounted in an inlet of said cryopump such that said flow restrictor restricts a flow of gas into said inlet.

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A third aspect provides a method of upgrading a cryopump comprising: removing a throttle plate mounted across an inlet of said cryopump for limiting flow into said cryopump; and replacing said throttle plate with a flow restrictor according to a first aspect.

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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.

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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.

25 BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present invention will now be described further, with reference to the accompanying drawings, in which:

Figure 1 shows a cryopump and flow restrictor plate according to the prior art;

Figure 2 shows a flow restrictor according to an embodiment;

- 30 Figure 3 shows a top view of the flow restrictor with the shielding plate removed;

Figure 4 shows a top view of the flow restrictor and a cryopump comprising the flow restrictor according to an embodiment; and

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Figure 5 shows a view towards the inlet of the flow restrictor from inside the pump according to an embodiment.

DESCRIPTION OF THE EMBODIMENTS

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

Embodiments provide a throttle plate, sputter plate or a flow restrictor that utilizes an indirect orifice/opening scheme arranged to inhibit preferential pumping of
10 type II gasses or radiation from negatively affecting the second stage frost or cryopanel. The idea is to allow monolithic type II gas storage on the second stage cryopanel increasing the amount of type II gas that can be stored. In this regard if the gas is pumped uniformly more can be stored, if one area builds condensed gas up more quickly than the others the gas partial pressure within
15 the pump will rise.

Flow restrictors of an embodiment act as an orifice (with one or multiple openings) and allow type II and type III gasses to enter the pump at a rate or speed that is controlled by the size and number of orifices. They are arranged so
20 that the orifices are at an angle to the pump inlet and no direct line of sight to the cryopanel is provided.

The cryopump is configured so that the flow restrictor operates at a temperature of 45K to 110K, that is it is connected to the first stage of a two-stage refrigeration
25 device. In embodiments the flow restrictor is mounted on the inner wall of the pumping chamber which is cooled by the first stage heat station. The second stage cryopanel operates between 8K to 16K and may have charcoal or similar adsorbent material for type III gas pumping. The second stage cryopanel may or may not be configured to shield type II gasses from the adsorbent material for
30 type III gas. In this regard panels 13 in the embodiment of Figure 4 may comprise charcoal covered cryopanel that are shielded by the upper cryopanel 12.

- The flow restrictor throttles the speed of the pump for type II and type III gasses so as to match the (PVD) process gas flow rate and achieve a predicted pressure within the vacuum chamber. The amount of openings or orifices should be
- 5 carefully designed so that the pumps provide a predictable and consistent pumping speed. When a flow restrictor is used in a pump inlet a higher vacuum is achieved below the flow restrictor opening and a lower vacuum on the chamber side.
- 10 Flow restrictor or throttle plate pumps are mainly used in a viscous or continuous flow regime, such as in physical vapour deposition PVD processes. With viscous flow to the flow restrictor any opening/orifice that has line of sight or “looks” directly at the pump’s second stage cryopanel can cause preferential gas pumping. Radiant heat loads are always present with cryogenic vacuum pumps,
- 15 but proper shielding can mitigate the effect on the second stage. The first stage of most cryopumps have much higher refrigeration capabilities so intercepting the heat load at the flow restrictor is advantageous. The second stage of most cryopumps have less refrigeration capabilities and should be shielded from high heat loads and uneven gas loading. Where preferential gas pumping through the
- 20 inlet openings/orifices is allowed, the line of sight path grows “spires” and these hamper the pump’s performance over time. Therefore inhibiting the gasses’ viscous flow to enter through the flow restrictor in a direct line to the second stage is advantageous for increased pumping performance.
- 25 In this regard, cryopumps are “capture” pumps, so any gasses that are cryopumped (below their vapor pressure) onto its surfaces will stay trapped until the cryopanel is “regenerated” or warmed to release them to the relief valve/rough valve. All cryopumps have a finite amount of gas that can be pumped before the pressure degradation of the pump makes it unusable for the
- 30 desired process. When a particular process has a very high flow rate of type II gasses the pump stores these gasses as frost on the second stage plate and when the frost reaches the flow restrictor, or the condensed gasses (frost) get too

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warm the pump will not operate as intended. The time between regenerations is mainly controlled by the pump's maximum storage capacity for type II gasses and the gas flow rate. Capture is very important to the pump user as increased capture reduces the frequency of regenerations. Providing a more uniform
5 capture increases the amount of gas that can be captured before the effects of the condensed gas inhibits the performance of the pump to a degree that a regeneration is required.

The flow restrictor or throttle plate of embodiments has a top or shielding plate
10 that may be circular but can be any shape. The shielding plate may be smaller than the inlet plate and there is a "spacer" or intermediate component between the two that separates the two plates by a sufficient amount to allow type II gasses to enter the cryopump. The flow path through the spacer may be substantially at 90° to the pump inlet. The "spacer" or intermediate piece
15 separates the shielding plate and inlet plate and provides a path for gas diverted by the shielding plate to flow between the two plates and across the outer edge of the inlet plate into the pump through the opening in the inlet plate. The opening may be circular but it could be any shape. The top or shielding plate may overhang the "spacer" to further shield radiation and unwanted gasses from
20 entering the cryopump.

A flow restrictor configured in this way allows for reduced radiant heat loading and provides monolithic frost pumping without the drawbacks of line of sight or preferential gas pumping. This reduction of uneven gas loading and radiation on
25 the second stage cryopanel keeps the second stage cryopanel colder and increases gas capture capabilities.

This flow restrictor is designed so that the gas is routed through openings/orifices that may be any shape in the intermediate spacer. This arrangement allows for
30 randomized gas pumping and provides a monolithic frost build-up substantially uniformly over the entire surface area of the second stage cryopanel. Such

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monolithic gas pumping is advantageous inhibiting frost on the second stage cryopanel from contacting the warmer first stage radiation shield or flow restrictor.

5 The shielding plate is important to maximize or at least increase the type II gas frost pumping and radiation abatement allowing for longer times between regenerations.

Figure 2 shows a flow restrictor 40 according to an embodiment. Flow restrictor 40 has in this embodiment a circular cross section and comprises a shielding
10 plate 1 mounted via lower surface 1A on an intermediate component 3 which is in the form of a cylinder with apertures 3A around the longitudinal surface. The intermediate component 3 is mounted on inlet component 2 which comprises protrusions 4 for mounting the flow restrictor 40 on the inner walls of a cryopump.

15 The flow restrictor 40 is mounted at the inlet of the cryopump and restricts flow into the pump. The shielding plate 1 shields the cryopanel within the cryopump from line of sight view of the inlet to the pump while the apertures 3A provide a route for gas to flow into the pump through a orifice in the middle of inlet component 2. This provides substantially uniform flow across the cross section
20 of the gas flow path provided by the orifice in component 2. The size and number of apertures 3A can be selected to restrict the flow of gas into the pump to a speed that may be required to maintain pressure within the pump at a desired rate.

25 Figure 3 shows a view from the top of the flow restrictor looking into the pump with the shielding plate 1 removed. This shows inlet component 2 with orifice 2A that provides the gas flow path into the pump. The upper surface of intermediate spacer component 3 is shown.

30 Figure 4 shows a cryopump according to an embodiment on which the flow restrictor is mounted. Flow restrictor is also shown as a side view and from above with the shielding plate 1 in place.

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The cryopump has a refrigerator unit 15 which cools a first stage refrigerator heat station 10 which is used to cool the housing on which the flow restrictor 40 is mounted and second stage refrigerator heat station 11 which is used to cool the upper cryopanel 12 and other cryopanel 13. These lower cryopanel 13 may be coated with an adsorbent material for adsorbing type III gases. The upper panel 12 shield the lower panels 13 from type II gases, which are condensed on the upper panel 12.

10 This figure shows the build-up of the condensed type II gases in the form of frost 14 formed from gas molecules captured on cryopanel 12. This illustrates how with the flow restrictor in place there is a uniform build-up of frost allowing significantly more gas to be captured before the frost reaches the flow restrictor. Having a more uniform gas flow and corresponding uniform capture and frost
15 build-up allows the time between regenerations to increase, in some embodiments by up to 50%.

Figure 5 shows a view from below the flow restrictor, showing the cryogenic bosses or feet 4 which are used to mount the flow restrictor on the inner housing of the cryopump. Figure 5 also showing the shielding plate viewed through the
20 orifice 2A in the inlet component 2. As can be seen the shielding plate 1 completely shields the orifice 2A from direct line of sight paths between the inside and outside of the pump.

25 The flow restrictor 40 of embodiments is adapted to be mounted within the inlet of a cryopump, in some embodiments on the inner wall of the pump housing. in embodiments a cryopump may be upgraded by removing any existing throttle plate and placing a flow restrictor 40 of an embodiment in the inlet, such that gas flow into the pump is diverted around the shielding plate via the intermediate
30 component to the orifice in the inlet component, thereby providing uniform gas flow across the cross section of the pump inlet.

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Although illustrative embodiments of the invention have been disclosed in detail 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
5 from the scope of the invention as defined by the appended claims and their equivalents.

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REFERENCE SIGNS

	1	shielding plate
	1A	lower surface of shielding plate
5	2	inlet component
	2A	orifice
	3	intermediate component
	3A	apertures in intermediate component
	4	cryogenic bosses
10	5	flow restrictor plate
	9	vacuum vessel
	10	first stage heat station
	11	second stage heat station
	12	cyropanel
15	13	Cryopanel with adsorbent
	14	frost
	14a	frost spires
	15	refrigeration unit
	40	flow restrictor
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CLAIMS

1. A flow restrictor for restricting a flow rate of gas flowing into a cryopump,
said flow restrictor being configured to be mounted in an inlet of said cryopump,
5 said flow restrictor comprising:
 an inlet component for providing a gas flow path into said cryopump;
 a shielding plate mounted to at least partially obscure said gas flow path
 though said inlet component; and
 an intermediate component linking said shielding plate to said inlet
10 component, said intermediate component comprising at least one aperture, said
at least one aperture defining at least one gas flow path into said cryopump;
wherein
 said shielding plate is configured to shield said gas flow path through said
inlet component such that when mounted on said cryopump there is no direct line
15 of sight path through said inlet component to a cryopanel within said cryopump.
2. A flow restrictor according to claim 1, wherein said inlet component has an
annular form delimiting an orifice, said orifice defining said gas flow path.
- 20 3. A flow restrictor according to claim 1 or 2, wherein said intermediate
component comprises a plurality of apertures.
4. A flow restrictor according to any preceding claim, wherein a surface of
said intermediate component comprising said at least one aperture lies at an
25 angle of between 120° and 60° to said shielding plate
5. A flow restrictor according to claim 4, wherein said surface of said
intermediate component comprising said at least one aperture is substantially
perpendicular to said shielding plate.
- 30 6. A flow restrictor according to any preceding claim, wherein said
intermediate component comprises a cylinder.

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7. A flow restrictor according to any preceding claim, wherein an outer periphery of said inlet component extends beyond an outer periphery of said shielding plate.

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8. A flow restrictor according to claim 7, wherein an outer periphery of said shielding plate extends beyond a perimeter of said orifice of said inlet component.

9. A flow restrictor according to any preceding claim, wherein said shielding
10 plate and said inner component have a substantially circular outer perimeter.

10. A flow restrictor according to any preceding claim, wherein said at least one aperture of said intermediate component is configured to restrict flow into said cryopump to a predetermined flow rate.

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11. A cryopump comprising:
a pump inlet;
a refrigeration unit;
a cryopanel configured to be cooled by said refrigeration unit; and
20 a flow restrictor according to any preceding claim, said flow restrictor being mounted in an inlet of said cryopump such that said flow restrictor restricts a flow of gas into said inlet.

12. A method of upgrading a cryopump comprising:
25 removing a throttle plate mounted across an inlet of said cryopump for limiting flow into said cryopump; and
replacing said throttle plate with a flow restrictor according to any preceding claim.

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