

GAS SEPARATION APPARATUS



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BACKGROUND OF THE INVENTION

1. Field of the Invention

5 The present invention relates to a gas separation apparatus for separating specific gases from a mixture gas containing a plurality of gases.

2. Description of the Related Art

Conventionally, various gases are used in a semiconductor
10 manufacturing processes depending on the process. For example, perfluoro compound (PFC) gas which is a mixture containing fluorine compounds such as CF_4 , NF_3 , C_2F_6 , C_3F_8 , SF_6 , and CHF_3 , is used as a reaction gas at the dry etching process or at the thin film forming process. In these processes, discharge gas is produced which
15 contains the PFC gas.

Because these discharge gases such as PFC cannot be discharged out of the manufacturing line as such, various methods are employed for treating these gases. The treating methods include (i) decomposition in which the PFC gas is decomposed by combustion,
20 catalyst heating, or plasma decomposition; (ii) membrane separation in which these materials are separated by a membrane; and (iii) subzero cooling separation in which the separation is achieved taking advantage of the difference in the boiling points of the gases.

25 However, in the above method (i), there are shortcomings in



that a complete decomposition is difficult and the gas cannot be recovered for reuse because the gas is decomposed and discharged. In the membrane separation (ii), although nitrogen in the discharge gas can be removed, the separation between CF_4 and NF_3 , or the like which have similar molecular size is difficult. In the above method (iii), the overall size of the apparatus becomes large, resulting in increased cost for the equipment and increased running cost. Moreover, because the boiling point difference between CF_4 and NF_3 is only 1 °C, the separation is difficult.

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SUMMARY OF THE INVENTION

One object of the present invention is to provide a gas separation apparatus capable of separating a mixture gas having a plurality of gas constituents inexpensively and with high purity.

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In order to achieve the object mentioned above, according to one aspect of the present invention, there is provided a gas separation apparatus for separating specific gases from a mixture gas to be treated containing the specific gases, the apparatus comprising: a concentrator for concentrating the specific gases within the mixture gas to be treated; and a separator for chromatographically separating the mixture gas, with the specific gases concentrated by the concentrator, into each of the plurality of gas constituents.

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In this manner, by using a separator which performs chromatographic separation, separation of specific gases, such,

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for example, as CF_4 and NF_3 , contained in the mixture gas to be treated, which are otherwise difficult to be separated, can be reliably achieved. The separated CF_4 and NF_3 can then be recovered and reused.

5 By providing a concentrator before the separator, the specific gases, for example, CF_4 and NF_3 , can be reliably separated at the separator.

According to another aspect of the present invention, there is provided a gas separation apparatus for separating specific gases
10 from the mixture gas to be treated containing the specific gases, the apparatus comprising: a separator for chromatographically separating the mixture gas to be treated into each of the plurality of gas constituents; and concentration means for independently concentrating the mixture gas separated into each of the plurality
15 of gas constituents and obtained at the separator; wherein the concentrated gases obtained by the concentrator are recovered and reused.

A carrier gas (for example, nitrogen) is included in the chromatographically separated specific gases, such, for example,
20 as CF_4 and NF_3 . By removing the carrier gas by the concentration means, the specific gases can be recovered and reused.

According to another aspect of the present invention, there is provided a gas separation apparatus for separating specific gases from a mixture gas to be treated containing the specific gases,
25 the apparatus comprising: a front concentrator for concentrating

the specific gases within the mixture gas to be treated; a separator for chromatographically separating the gases, with the specific gases concentrated by the upstream concentrator, into each of the plurality of constituents; and rear concentrators for independently
5 concentrating the mixture gas separated into each of the plurality of gas constituents and obtained at the separator; wherein the concentrated gas obtained by the rear concentrators are recovered and reused.

With this apparatus, the specific gases can be separated
10 effectively and in high concentrations. Therefore, each of the obtained specific gases can be easily reused.

According to another aspect of the present invention, it is preferable that a mixture gas containing the specific gases having a plurality of gas constituents is the PFC gas discharged from a
15 semiconductor manufacturing process and the mixture gas to be treated contains nitrogen as another gas.

According to another aspect of the present invention, it is preferable that the PFC gas contains one of fluorine compounds having at least one of the elements C, N, and S as a composition
20 element.

According to another aspect of the present invention, it is preferable that the PFC gas includes one of CF_4 , NF_3 , C_2F_6 , C_3F_8 , SF_6 , or CHF_3 .

According to another aspect of the present invention, it is
25 preferable that the above-mentioned concentration means is either

a membrane separator which takes advantage of the permeability/impermeability of a membrane or a subzero cooling separator which takes advantage of the difference in boiling point. With such a concentration means, concentration of the PFC gas, for
5 example, can be effectively performed.

According to another aspect of the present invention, it is preferable that a plurality of chromatographic columns are provided and used in sequence. By using a plurality of columns, the separation process can be performed almost continuously.

10 According to another aspect of the present invention, it is preferable that the gases other than the specific gases separated at the separator contains nitrogen as its main constituent and the nitrogen gas is reused in a given usage.

According to another aspect of the present invention, it is
15 preferable to perform a process to remove gas constituents other than the nitrogen gas on the gas containing nitrogen gas as its main constituent.

BRIEF DESCRIPTION OF THE DRAWINGS

20 Fig. 1 is a diagram showing a schema of one of the embodiments of the present invention.

Fig. 2 is a diagram showing a structure of a chromatographic separator which consists of a plurality of columns.

Fig. 3 is a diagram showing the treatment of nitrogen.

DESCRIPTION OF PREFERRED EMBODIMENT

A preferred embodiment of the present invention will now be described referring to the drawings.

A PFC gas is supplied in a manufacturing process 10 such as etching or thin film formation at a semiconductor manufacturing plant. A discharge gas containing the PFC gas is thus produced. The inlet side of a vacuum pump 12 is connected to the path for the discharge gas and the discharge gas containing the PFC gas is discharged from the manufacturing process 10 by the vacuum pump 12. As the mixed PFC gas, CF_4 , NF_3 , C_2F_4 , SF_6 , or the like or a combination thereof are suitably used. In this example, the PFC gas contains CF_4 and NF_3 . Here, because the PFC gas decomposes in the manufacturing process 10 to generate hydrofluoric acid, the discharge gas also contains hydrofluoric acid. Because of this, if the discharge gas is directly introduced into the vacuum pump 12, the vacuum pump 12 may be damaged. In order to cope with this problem, nitrogen gas is supplied as a diluting gas, from the discharge gas path to the vacuum pump 12, to dilute the discharge gas.

The outlet side of the vacuum pump 12 is connected to a scrubber 14. The discharge gas which is diluted by nitrogen is supplied to the scrubber 14. The scrubber 14 employs water shower to dissolve and absorb hydrofluoric acid (HF) within the discharge gas into water.

The discharge gas from the scrubber 14 is then introduced to

a dewatering device 16, where water is removed. The discharge gas from the scrubber 14 contains a large amount of water and it is desirable to remove water for the subsequent processes. Any form of dewatering device can be used as the dewatering device 16, but
5 it is preferable to employ a dewatering device in which water is removed by reducing the temperature of the discharge gas.

The discharge gas containing the PFC gas and nitrogen thus obtained is supplied to a concentrator 18. The concentrator 18 is for removing nitrogen and is preferably a membrane separator which
10 uses a gas permeation membrane. With this structure, nitrogen is separated from the discharge gas and the PFC mixed gas (CF_4 and NF_3 in the embodiment) is concentrated. It is also possible to use a subzero cooling device as the concentrator 18. More specifically, although the boiling points for CF_4 and NF_3 are similar (-128°C and
15 -128.8°C , respectively), the boiling point of nitrogen is significantly different (-195°C). Nitrogen can thus be easily separated using this difference in the boiling points in order to concentrate the PFC gas.

After PFC gas is concentrated in this manner, the gas is
20 supplied to a chromatographic separator 20. The chromatographic separator 20 includes a column filled with a desired filler. The gas is passed through the column. In this manner, the gas is separated into the constituents because the constituents have different retention times due to difference in the affinity
25 (tendency for adsorption and distribution coefficient) of the gas

constituents with respect to the filler. As a filler, for example, silica gel or molecular sieve can be used for separating CF_4 and NF_3 . In the chromatographic separator 20, nitrogen is used as a carrier gas and CF_4 and NF_3 are separated by sequentially desorbing and discharging CF_4 and NF_3 adsorbed on the filler. When a fraction having both CF_4 and NF_3 is generated, it is preferable to return this fraction to the separator inlet side.

For example, while passing nitrogen gas, a predetermined amount of discharge gas can be mixed with nitrogen gas, and a fraction containing CF_4 and a fraction containing NF_3 can be separately collected.

It is also preferable to provide a plurality of columns as the chromatographic separator 20, supply the discharge gas to each column in sequence, and collect each fraction from each column in sequence.

Fig. 2 shows a configuration example in which four columns 20a, 20b, 20c, and 20d are provided, and fractions are obtained by supplying the discharge gas to the columns in sequence. For example, nitrogen can be continuously supplied to the columns 20a, 20b, 20c, and 20d as a carrier gas, and the discharge gas can be introduced to the columns in sequence by switching the valves at the column inlet side in sequence. Because gas of nitrogen, gas of CF_4 and nitrogen, gas of CF_4 , NF_3 and nitrogen, and gas of NF_3 and nitrogen flows out from each of the columns 20a, 20b, 20c, and 20d, in that order, the gases can be separated and discharged by

switching the valves at the column exit side in sequence and actuating corresponding one of vacuum pumps VP. The gas containing both CF_4 and NF_3 is circulated to the column into which the discharge gas is being introduced.

5 In this manner, gas of nitrogen, gas of CF_4 and nitrogen, and gas of NF_3 and nitrogen are obtained at the exit of the chromatographic separator 20.

10 It is preferable to perform the collection of the gas for each constituent at the exit of the chromatographic separator 20 and the switching of the valves in Fig. 2 based on an analysis result of the gas at the exit. For example, constituents can be detected using a differential thermal detector (TCD) or Fourier transform-infrared analyzer (FT-IR), and the control can be performed based on the analysis.

15 With this process, the gas is separated into the constituents, and thus, in the fractions of CF_4 and nitrogen, and of NF_3 and nitrogen, a pure mixture can be obtained with almost no other materials present.

20 The obtained gas of CF_4 and nitrogen is supplied to a concentrator 22 and the obtained gas of NF_3 and nitrogen is supplied to a concentrator 24. As the concentrators 22 and 24, a membrane separator or a subzero cooling device is used, similar to the concentrator 18. In particular, by circulating the concentrated gas several times in a membrane separator or by using a multiple
25 membrane separator, or using a subzero cooling separator, almost

100% of the nitrogen can be separated, leaving a pure, 100% concentration of CF_4 gas and NF_3 gas.

The obtained CF_4 gas and NF_3 gas can then be recovered and reused at the manufacturing process 10.

5 In this manner, in the embodiment, the separation of CF_4 and NF_3 , which is difficult in other separation methods, can be reliably achieved using the chromatographic separator 20. The separated CF_4 and NF_3 can be recovered and reused.

10 In particular, in the embodiment, a concentrator 18 is provided before the chromatographic separator 20 for removing nitrogen once. In this manner, CF_4 and NF_3 can be reliably separated at the chromatographic separator 20 using nitrogen as a carrier gas. The concentrations of CF_4 and NF_3 in the fractions can be maintained at a certain high concentration.

15 Moreover, in the embodiment, for the fractions of gas of CF_4 and nitrogen, and gas of NF_3 and nitrogen, nitrogen is removed by separate concentration processors 22 and 24. Because of this, almost 100% of nitrogen can be removed, so that CF_4 and NF_3 can be reused at the manufacturing process 10.

20 The PFC gas may include, in addition to CF_4 and NF_3 , C_2F_6 and SF_6 , etc. These PFC gases can be separated relatively easily by various devices. In the chromatographic separator 20, these PFC gas constituents appear as fractions that are far apart, and thus, the fraction containing these PFC gas constituents can be
25 respectively separated from the fraction separated as nitrogen in

the above example.

Also, nitrogen is discharged at the concentrator 18, chromatographic separator 20, and concentrators 22 and 24. Nitrogen, on the other hand, is necessary as the diluting gas before the vacuum pump 12 and as the carrier gas for the chromatographic separator 20. It is therefore preferable to reuse the obtained nitrogen gas. The decision on where the obtained nitrogen is reused can be arbitrary, but because the diluting gas before the vacuum pump 12 is close to a crude gas, it is preferable to reuse nitrogen as the diluting gas.

It is highly probable that the nitrogen gas to be reused contains some amount of the PFC gas. Therefore, it is preferable to process the nitrogen gas to remove the PFC gas. As the process, it is preferable to employ a known method for decomposing the PFC gas, such, for example, as plasma decomposition process, combustion, and catalyst heating process. It is also possible to perform the membrane process, subzero cooling separation, and chromatographic separation again for separating the PFC gas and reuse nitrogen.

Fig. 3 shows an example where the plasma decomposition process is employed. As shown, nitrogen discharged at the concentrator 18, 22, and 24 is subjected to the plasma decomposition process at the plasma decompose device 26 to decompose the PFC gas, and the obtained nitrogen is reused as the diluting gas or the carrier gas.

Example 1

As a sample discharge gas, nitrogen gas was prepared having

0.01% of CF_4 and 0.01% of NF_3 (volume percent). The sample discharge gas was introduced to the concentrator 18 of the apparatus shown in Fig. 1, and processing experiment was performed at each of the subsequent processes.

5 A membrane separator was used as the concentrator 18. the sample gas was concentrated using the membrane separator to a point where the both concentrations for CF_4 and NF_3 are equal to or greater than 10%. Then, the concentrated mixed gas was passed through the chromatographic separator 20 with the column filled with silica
10 gel and using nitrogen as a carrier. As a result, gas of CF_4 and gas of NF_3 were separated and discharged in that order at the column exit, due to the difference in the retention times. Respective concentrations of CF_4 and NF_3 in nitrogen was 0.01% and the purity was 100%. By removing nitrogen at the concentrators 22 and 24
15 (membrane separators), gases of CF_4 and NF_3 were obtained each with almost 100% concentration.

The analysis of the nitrogen obtained at the concentrator 18, chromatographic separator 20, and concentrators 22 and 24 indicated that the nitrogen gas contained 10 ppm of PFC gas. The PFC gas was
20 almost completely decomposed and rendered harmless by applying a plasma decomposition process to the obtained nitrogen. It was thus confirmed that the nitrogen gas is usable as a diluting gas before the vacuum pump 12 or as a carrier gas for the chromatographic separator 20.

What is claimed is:

1. A gas separation apparatus for separating specific gas constituents from a mixture gas to be treated containing a plurality
5 of gas constituents, said apparatus comprising:
a concentrator for concentrating the specific gas constituents within said mixture gas to be treated; and
a separator for chromatographically separating the gas, with the specific gas constituents concentrated by the concentrator,
10 into each of the plurality of gas constituents.
2. A gas separation apparatus of claim 1, wherein
said mixture gas having a plurality of gas constituents is PFC gas discharged from a semiconductor manufacturing process and
15 said gas to be treated contains nitrogen as another gas.
3. A gas separation apparatus of claim 2, wherein
said PFC gas contains one of fluorine compounds including at least one element of C, N, and S as a composition element.
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4. A gas separation apparatus of claim 3, wherein
said PFC gas includes one of CF_4 , NF_3 , C_2F_6 , C_3F_8 , SF_6 , or CHF_3 .
5. A gas separation apparatus of claim 1, wherein
25 said concentrator is a membrane separator which takes

advantage of the permeability/impermeability of a membrane.

6. A gas separation apparatus of claim 1, wherein
said concentrator is a subzero cooling separator which takes
5 advantage of the difference in the boiling points.

7. A gas separation apparatus of claim 1, wherein
said chromatographic separator includes a plurality of
chromatographic columns which are used in sequence.

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8. A gas separation apparatus of claim 1, wherein
gas constituents other than the specific gas constituents,
separated at said concentrator or at said separator, contain
nitrogen as the main constituent and the nitrogen gas is reused
15 for a given usage.

9. A gas separation apparatus of claim 8, wherein
a process for removing gas constituents other than nitrogen
gas is performed on said gas containing nitrogen gas as the main
20 constituent.

10. A gas separation apparatus for separating specific gas
constituents from a mixture gas to be treated containing a plurality
of gas constituents, said apparatus comprising:

25 a separator for chromatographically separating a mixture

gas to be treated into each of the plurality of gas constituents;
and

concentrators for separately concentrating the gas separated
into each of the plurality of gas constituents and obtained at the
5 separator; wherein

the concentrated gases obtained by said concentrators are
recovered and reused.

11. A gas separation apparatus of claim 10, wherein

10 said mixture gas having a plurality of gas constituents is
PFC gas discharged from a semiconductor manufacturing process and
said gas to be treated contains nitrogen as another gas.

12. A gas separation apparatus of claim 11, wherein

15 said PFC gas contains one of fluorine compounds including at
least one element of C, N, and S as a composition element.

13. A gas separation apparatus of claim 12, wherein

said PFC gas includes one of CF_4 , NF_3 , C_2F_6 , C_3F_8 , SF_6 , or CHF_3 .

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14. A gas separation apparatus of claim 10, wherein

at least one of said concentrator is a membrane separator
which takes advantage of the permeability/impermeability of a
membrane.

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15. A gas separation apparatus of claim 10, wherein
at least one of said concentrator is a subzero cooling
separator which takes advantage of the difference in the boiling
points.

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16. A gas separation apparatus of claim 10, wherein
said chromatographic separator includes a plurality of
chromatographic columns which are used in sequence.

10 17. A gas separation apparatus of claim 10, wherein
gas constituents other than the specific gas constituents,
separated at said concentrators or at said separator, contains
nitrogen as the main constituent and the nitrogen gas is reused
for a given usage.

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18. A gas separation apparatus of claim 17, wherein
a process for removing gas constituents other than nitrogen
gas is performed on said gas containing nitrogen gas as the main
constituent.

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19. A gas separation apparatus for separating specific gas
constituents from a mixture gas to be treated containing a plurality
of gas constituents, said apparatus comprising:

a front concentrator for concentrating the specific gas
25 constituents within said mixture gas to be treated;

a separator for chromatographically separating the gas, with the specific gas constituents concentrated by the concentrator, into each of the plurality of gas constituents; and

rear concentrators for separately concentrating the gas
5 separated into each of the plurality of gas constituents and obtained at the separator; wherein

the concentrated gases obtained by said rear concentrators are recovered and reused.

10 20. A gas separation apparatus of claim 19, wherein
said mixture gas having a plurality of gas constituents is PFC gas discharged from a semiconductor manufacturing process and said gas to be treated contains nitrogen as another gas.

15 21. A gas separation apparatus of claim 20, wherein
said PFC gas contains one of fluorine compounds including at least one element of C, N, and S as a composition element.

22. A gas separation apparatus of claim 21, wherein
20 said PFC gas includes one of CF_4 , NF_3 , C_2F_6 , C_3F_8 , SF_6 , or CHF_3 .

23. A gas separation apparatus of claim 19, wherein
at least one of said concentrator is a membrane separator which takes advantage of the permeability/impermeability of a
25 membrane.

24. A gas separation apparatus of claim 19, wherein
at least one of said concentrator is a subzero cooling
separator which takes advantage of the difference in the boiling
points.

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25. A gas separation apparatus of claim 19, wherein
said chromatographic separator includes a plurality of
chromatographic columns which are used in sequence.

10 26. A gas separation apparatus of claim 19, wherein
gas constituents other than the specific gas constituents,
separated at said concentrators or at said separator, contain
nitrogen as the main constituent and the nitrogen gas is reused
for a given usage.

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27. A gas separation apparatus of claim 26, wherein
a process for removing gas constituents other than nitrogen
gas is performed on said gas containing nitrogen gas as the main
constituent.