

SPECIFICATION

[Name of the Invention]

Vacuum Exhaust Apparatus and Drive Method of Vacuum Exhaust Apparatus

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[Technical Field]

This invention relates to a vacuum exhaust apparatus, for example, for semiconductor manufacturing equipment and more particularly to a vacuum exhaust apparatus of the energy conservation type and a driving method of the vacuum exhaust apparatus to reduce consumed electric power.

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[Background of the Technique]

Oil-sealed rotary vacuum pumps were used for early semiconductor manufacturing equipments in most cases. Consumed electric power of the oil-sealed rotary vacuum pump is generally little and it has the construction by which low ultimate pressure can be easily obtained. However, the following points should be cared where the oil-sealed rotary pump is used in the semiconductor manufacturing equipment:

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(1) The gasses used in the semiconductor manufacturing equipment are strongly reactant in most cases. When such gas is exhausted, it reacts with vacuum pump oil and so produces reaction materials which make sometimes the vacuum pump to be impossible to rotate or the pump oil to be deteriorated in lubrication.

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(2) Vapor of the vacuum pump oil diffuses into the vacuum treatment or processing chamber and contaminates it.

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(3) Used vacuum pump oil contains arsenic compound and phosphorus compound as toxic material in most cases. Treatment of such harmful industrial waste requires much cost and the number of the management procedures is much. From the above grounds, recently dry vacuum pump (called also "dry-sealed vacuum pump" according to the international standard ISO/DIS3529/

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II -1975) which does not use sealing oil, is used instead of the oil-sealed rotary vacuum pump.

The dry vacuum pump can vacuum-pump a chamber from atmosphere and does not contain seal oil in its compression chamber. It is so-called a mechanical vacuum pump. Positive displacement types as Roots type vacuum pump, crow type vacuum pump and screw type are used as the dry vacuum pump in most cases. These vacuum pumps all have the construction of two axes to which a pair of rotors is fixed, spacing a little gap from each other. The paired rotors are rotated in opposite directions for the vacuum pumping. The life is long because of non-contact portion. It can exhaust also solid components contained in the gas sucked from the semiconductor manufacturing equipment. Further, resistance to corrosive gas can be easily imparted to the positive displacement type.

Thus, a dry vacuum pump has been substituted with the oil-sealed rotary vacuum pump in the semiconductor manufacturing equipment. However, there is the problem that the required electric power of the dry vacuum pump is larger than that of the oil-sealed vacuum pump.

It is required to save the consumption of energy from the ecological problem. And it is required to reduce the cost of the manufacture of the semiconductor. From the above requirements, it is requested to reduce the consumed electric power of the dry vacuum pump to less than 50% of the present.

For example, the Roots-type dry vacuum pump is provided with plural rotors fixed to the axes, adjacent each other. The paired rotors are spaced by a little gap from each other and rotated in opposite directions to suck and exhaust gas. The rotors constitute normally three to six pump chambers. The respective pump chambers effect pumping actions in regular sequences. The gas to be exhausted is displaced from the earlier or former stages to the latter stages. The gas pressure rises with the displacement. Accordingly, the throughput of the latter stages may be smaller than that of the earlier stages.

In the multi-stage Roots-type dry vacuum pump, the external forms of the rotors all are made to be the same from the viewpoints of the simple manufacture and the synchronization of the rotations of the rotors at the present. For the above reason, the thickness of the rotors is stepwise smaller towards the outlet side from the inlet side so as to reduce stepwise the throughputs of the pump chambers.

In the Roots-type dry vacuum pump, gas to be exhausted, is temporarily confined in a space formed by an inner surface of a casing and a hollow on the surface of the rotor and the space comes to communicate with the outlet side space, with a further rotation of the rotor. On that communication, the outlet side gas is reversely flowed into the space. An ultimate pressure of about 1 to 10Pa can be obtained by the Roots-type dry vacuum pump. The pressure from the ultimate pressure to about 3kPa is a normal pressure. The outlet pressure is an atmospheric pressure. Accordingly, in order to maintain the inlet side at the reduced pressure, the gas reversed into the rotor chamber in the compression process should be pushed back. About 70 to 80 percentages of the total electric power of the pump is consumed to receive the back flow or push the flow gas from the atmosphere in the rotor chamber of the last stage.

In the Roots-type dry vacuum pump, the power of the final stage becomes little with the decrease of the amount of the gas to be pushed back. Accordingly, as above described, the thickness of the rotor of the latter stage is thinned so as to reduce the throughput. Thus, when the throughput of the rotor chamber of the last stage is so set as to be little, the required power of the pump is reduced in the range of the normal pressure, and so the energy conservation is obtained at the present.

The exhaust principle of the crow-type dry vacuum pump is quite the same as that of the Roots-type dry vacuum pump, although the shapes of the rotors are different between the Roots-type and the crow-type. On the other hand, the gas is transported axially along the space constituted by the two screw grooves, in the screw type. The gas of the outlet portion is flowed into the space formed

by the screw grooves, to compress the gas. That is equal to the Roots-type dry vacuum pump.

Since the screw grooves are continuous, the pitches of the screw grooves are continuously reduced towards the last stage. Thus, the throughput is made smaller towards the last stage, although the throughput is arbitrarily reduced towards the last stage in the Roots-type dry vacuum pump and the crow-type dry vacuum pump. However, the pitch changes of the screw grooves are limited to some extent. Accordingly, blocks different in screw pitches are prepared, and so combined with each other as to reduce the throughput of the last stage pump chamber.

There will be further described about the above.

When the rotors are equal in size as shown in Fig.18, the pumping speed changes with the inlet pressure (Pa) as shown by letter a in Fig.21. When the two rotors of the former stage are equal in size, those of the middle stage are smaller than the former two, and those of the latter stage are further smaller than those of the middle stage, as shown in Fig.19, the pumping speed changes with the inlet pressure as shown by the letter b in Fig.21. When the two rotors of the latter stage are further smaller in comparison with the case of Fig.19, as shown in Fig.20, the pumping speed changes with the inlet pressure, as shown in Fig.21.

Fig.22 shows the relationships between the consumed electric power and the inlet pressure, in the respective cases of Fig.18, Fig.19 and Fig.20. Under the less pressure than 10^2 Pa which is a normal pressure for the semiconductor manufacturing equipment, the consumed electric power is the smallest in the case of Fig.20, that is smaller than the case of Fig.19 and that is the largest in the case of Fig.18, as shown by letters c', b' and a'.

Throughput of the last stage is designed in accordance of use object of the pump. For example, in the multi-stage Roots-type dry vacuum pump, throughput of the pump chamber of the last stage is so designed as to be about 50% of that of the first stage. Much compression heat generates within the range of the

normal temperature. In an etching equipment and a low pressure CVD equipment for semiconductor manufacturing apparatus, gas generating in its reaction process contains component which deposits solid material at the gas concentration beyond the saturation vapor pressure in the vacuum exhaust apparatus. In the exhaust of such gas, a dry vacuum pump should be heated to a high temperature such as about 100 to 160°C, in order to prevent deposit of solid material. For that purpose, a dry vacuum pump of pumping speed ratio of about 50%, as above described can be employed since compression heat can be utilized to heat effectively the dry vacuum pump. Gas exhausted from the sputtering apparatus and the vapor deposition apparatus mainly inert gas such as argon and helium. At that case, it is not necessary to heat the dry vacuum pump. Accordingly, a dry vacuum pump, the consumed power of which is as little as possible, is required. At that case, the throughput of the pump chamber of the last stage is so designed as to be about 20 to 25% of that of the pump chamber of the first stage. At that case, the consumed power in the ultimate pressure can be reduced to 30 to 60% of that of the dry vacuum pump in which the throughput of the last stage is about 50% of that of the first stage.

When the throughput of the pump chamber of the last stage is less than 20% of the throughput of the first stage in the dry vacuum pump which is not required to be heated at the high temperature, more energy can be conserved. However, mechanical trouble is apt to occur. For example, when the throughput of the pump chamber of the last stage is about 25% of that of the first stage in the dry vacuum pump of the class which is used at the maximum pumping speed of 80m³/Hr, the thickness of the rotor of the first stage is generally about 30mm. At that case, the thickness of the rotor of the last stage is equal to 7.5mm. The mechanical strength of the rotor of the last stage is little. The right angle of the rotor side surface to the axis is difficult to be manufactured. And the gap between the rotor side surface and the partition wall is difficult to be maintained 0.1mm to 0.2mm.

On the other hand, there is disclosed a vacuum exhaust apparatus in the

Japanese Patent Opening Gazette No.129384/1994 in which a first vacuum pump of large exhaust amount and a second vacuum pump of small exhaust amount but capable of sufficiently low pressure, are connected with each other, and by which total electric power can be reduced. Particularly, as shown in
5 Fig.23, an exhaust pipe 7 is connecting a first exhaust port 5 formed at a middle portion of a connecting portion between the first pump and the second pump, with a second exhaust port 6 formed at the exhaust side of the second pump 4. A control valve 8 is arranged for opening and closing the exhaust pipe 7 at the middle portion, and it is opened and closed by the pressure of the suction side of
10 the first pump 3. A vacuum exhaust apparatus 2 is disclosed which can reduce total consumed power thereby. In Fig.23, the first vacuum pump 3 is modeled as a vacuum pump of a direct acting type.

A reference numeral 9 represents an adsorption tower for treating reaction gas contained in the exhausted gas.

15 The vacuum exhaust apparatus 2 operates as the followings: Fig.23 shows the situation directly after the start of the exhaust. The control valve 8 is opened. The first and second pumps 3 and 4 are driven. The inlet pressure of the first pump 3 is about equal to the level of the atmosphere. The amount of the exhaust gas is large. While the outlet portion of the first pump 3 does not become less
20 than the atmosphere, also by the second pump 4 driven at the same time, the control valve 8 is opened, Gas of sufficiently high density is exhausted by the first and second pumps 3 and 4.

Thereafter, when the outlet side of the first pump 3 is exhausted to a predetermined pressure less than the atmosphere by the second pump 4, the
25 control valve 8 is closed. Thus, only the second exhaust port 6 formed at the exhaust side of the second pump 4 communicates with the exhaust side of the pump.

At that time, the outlet side of the first pump 1 is maintained at the sufficiently low pressure.

30 The back flow gas to the first pump 3 is greatly reduced. The power

required for pushing the reverse gas backward can be surely reduced. Thus, the energy of the consumed electric power of the first pump 3 can be conserved.

However, in the vacuum exhaust apparatus 2, the energy of the whole vacuum exhaust system including the first pump 3 cannot be always effectively conserved, although the consumed electric power of the first pump 3 can be surely reduced.

Fig.24 shows a conduit diagram of a vacuum exhaust apparatus of the prior art connected to a vacuum processing chamber for manufacturing semiconductor. In a vacuum exhaust apparatus 10 of Fig.24, a vacuum processing chamber 1 is connected to a dry vacuum pump 20 of pumping speed 1000L/min through an exhaust pipe 12.

A main valve 13 of large diameter is arranged in the exhaust pipe 12. A by-pass valve 14 of small diameter is arranged in parallel with the main valve 13. Further, a pressure gauge 19 for measuring the pressure of the vacuum processing chamber 1 is attached to the exhaust pipe 12.

Generally, the vacuum processing chamber 1 of the semiconductor manufacturing apparatus contains fine particles which are apt to fly up, and to be attached to a semiconductor wafer put in the vacuum processing chamber 1, resulting in bad semiconductor.

When the vacuum processing chamber 1 is exhausted from atmosphere to vacuum, the main valve 13 and the by-pass valve 14 are closed, and the dry vacuum pump 20 is driven. Slow exhaust is effected with the opening of the by-pass valve 14. When it is confirmed that the pressure of the vacuum processing chamber 1 reaches a predetermined pressure, or when it is confirmed that a predetermined time has lapsed, the main valve 13 is opened. Such driving method is adopted.

When the slow exhaust is effected with the valve operation, or namely when the slow exhaust is effected with the by-pass valve 14 arranged in parallel with the main valve 14, a control apparatus for opening the main valve 13 in accordance with the pressure of the vacuum processing chamber 1 is required in

addition to the by-pass valve 14.

Further, a butterfly valve capable of control of valve opening may be used instead of the main valve 13 and by-pass valve 14 for effecting the slow exhaust. At that case, the valve opening is made small at the early stage of the exhaust, and then made larger in accordance with the lowering of the pressure of the vacuum processing chamber 1. However, the butterfly valve itself and an opening control apparatus for valve opening are expensive and raise cost up.

On the other hand, also when the exhaust is effected with the first pump 3 and second pump 4 in the vacuum exhaust pump 2 of the Japanese Patent Opening Gazette No.129384/1994 as shown in Fig.23, the fine particles fly up in the vacuum processing chamber 1 and they contaminate the semiconductor wafer.

The object of the invention is to provide a vacuum exhaust apparatus by which much energy conservation effect can be obtained by mere addition of simple construction to a usual dry vacuum pump.

Further object of the invention is to provide a drive method of a vacuum exhaust apparatus which can effect slow exhaust without any machine or apparatus for slow exhaust.

[Disclosure of Invention]

A vacuum exhaust apparatus and a drive method of the same are constructed for achieving the above objects as following:

In a vacuum exhaust apparatus of the invention, an inlet side of an auxiliary pump is connected to an outlet side of a pump chamber of a middle stage or of a last stage of a main pump.

It is preferable that the throughput of the auxiliary pump is smaller than that of the main pump, and that at least one pump chamber of a latter stage of the main pump is smaller than pump chambers of a former stage of the main pump. An exhaust pipe is connected to the outlet side of the pump chamber of the last stage of the main pump. A check valve which permits gas to flow only in the

direction towards the atmosphere, is connected to the exhaust pipe. It is preferable that the auxiliary pump is connected in parallel with the check valve. Plural check valves may be connected in series with each other instead of the one check valve. It is preferable that it includes a ball valve body floatable in a valve chamber. When the pressure of the exhaust gas of the main pump becomes higher than a predetermined value, the ball valve body floats to open the valve. When the pressure of the exhaust gas of the main pump becomes smaller than the predetermined value, the ball valve body seats on the downwards valve seat by the self-weight to close the valve. The ball valve body consists of hollow metal ball. It is preferable that the surface of the metal ball is covered with rubber. Further, when the two check valves are connected in series with each other, it is preferable that a space between the two check valves is connected to the inlet side of the auxiliary pump.

And a vacuum exhaust apparatus of this invention comprises a main pump, a check valve connected to the outlet side of the main pump and permitting gas to flow only from the main pump toward the atmosphere side, and an auxiliary pump arranged in parallel with the check valve connected to the outlet side of the main pump. Throughput of the auxiliary pump is smaller than that of the main pump. It is preferable that the auxiliary pump is driven at less than 3% of the pumping speed of the main pump under the inlet pressure 400Pa. It is preferable at that case that the main pump is the positive displacement type dry vacuum pump or a composite type consisting of plural vacuum pumps of the above type connected in series with each other. Further, it is preferable that plural main pumps are connected in parallel with each other, and an auxiliary pump is connected at the inlet port, connected to the outlet ports of the main pumps respectively. Further, it is preferable that the ultimate pressure of the auxiliary pump is less than 20kPa and it is a sliding vane rotary vacuum pump (Gede type), piston type, diaphragm type (membrane type) or scroll type.

In a driving of a vacuum exhaust apparatus of the invention, a main pump connected to a vacuum processing chamber, a check valve connected to the

outlet side of the main pump and an auxiliary pump connected to the outlet of the main pump in parallel with the check valve are provided in a vacuum exhaust apparatus for exhausting the vacuum processing chamber, and when said vacuum processing chamber is exhausted from the atmosphere or nearly from the atmosphere, said auxiliary pump is first driven, and after the pressure of said vacuum processing chamber has reached the predetermined pressure, said main pump is started to be driven.

Thus the slow exhaust is effected without using the machine or apparatus for slow exhaust. Further, it is possible that the auxiliary pump is first driven and the main pump is started at the low speed or the low throughput before the pressure of the vacuum processing chamber reaches the predetermined pressure, and the rotational speed of the main pump is gradually raised in accordance with the pressure of the vacuum processing chamber.

[Brief Description of the Drawings]

Fig. 1 is a schematic view of a vacuum exhaust apparatus according to one embodiment of this invention in which a multi-stage Roots-type dry vacuum pump is used as a main pump;

Fig.2 is a schematic view of a vacuum exhaust apparatus of one modification according to one embodiment of this invention in which a multi-stage Roots-type dry vacuum pump is used as a main pump;

Fig.3 is a schematic view of a vacuum exhaust apparatus of another modification according to one embodiment of this invention in which a multi-stage Roots-type dry vacuum pump is used as a main pump;

Fig.4 is a schematic view of a vacuum exhaust apparatus of further modification according to one embodiment of this invention in which a multi-stage Roots-type dry vacuum pump is used as a main pump;

Fig.5 is a schematic view of a vacuum exhaust apparatus of still further modification according to one embodiment of this invention in which a multi-stage Roots-type dry vacuum pump is used as a main pump;

Fig.6 is a cross-sectional view showing one example of a check valve used in a vacuum exhaust apparatus according to one embodiment of this invention;

Fig.7 is a schematic conduit arrangement view showing a vacuum exhaust apparatus according to another embodiment of this invention;

5 Fig. 8 is a cross-sectional view showing one example of a check valve used in the vacuum exhaust apparatus as shown in Fig.7 according to the other embodiment of this invention;

Fig. 9 is schematic conduit arrangement view showing one modification of the vacuum exhaust apparatus according to the other embodiment of this
10 invention;

Fig.10 is a cross-sectional view showing the detail of the check valve used in the vacuum exhaust apparatus as shown in Fig.9 according to the other embodiment of this invention;

Fig. 11 is a schematic conduit arrangement view showing another
15 modification of the vacuum exhaust apparatus according to the other embodiment of this invention;

Fig. 12 is a view explaining operation of the vacuum exhaust apparatus of the embodiment of this invention, showing the relationship between the inlet pressure of the main pump and the consumed power of the whole apparatus;

20 Fig. 13 is a view explaining operation of the vacuum exhaust apparatus of the embodiment of this invention, showing the relationship between the pumping speed ratio of the main pump to the auxiliary pump and the consumed power ratio of the main pump to the auxiliary pump;

Fig.14 is a view showing the relationship between the pumping speed and
25 the consumed power of a typical auxiliary pump;

Fig.15 is a view showing the consumed power characteristic of the vacuum exhaust apparatus according to the embodiment of this invention;

Fig. 16 is a view showing the relationship between the inlet pressure and the pumping speed of the vacuum exhaust apparatus of the embodiment of this
30 invention;

Fig.17 is a schematic conduit arrangement view showing further modification of vacuum exhaust apparatus according to the embodiment of this invention;

Fig.18 is a schematic view showing a multi-stage Roots-type dry vacuum pump in which all of the rotors are equal in size;

Fig.19 is a schematic view showing a multi-stage Roots-type dry vacuum pump in which the rotors are different in size at the former stage, middle stage and latter stage

Fig.20 is a schematic view showing a multi-stage Roots-type dry vacuum pump in which latter two are smaller than those of Fig.19.

Fig 21 is a view of the relationship between the inlet pressure and the pumping speed of the multi-stage Roots-type dry vacuum pump having the rotors of Fig.18, Fig.19 and Fig.20, respectively;

Fig.22 is a view of the relationship between the inlet pressure and the consumed power of the multi-stage Roots-type dry vacuum pump having the rotors of Fig.18, Fig.19 and Fig.20, respectively;

Fig.23 is schematic view of a vacuum exhaust apparatus of the prior art which can reduce consumed power;

Fig.24 is a schematic view of a vacuum exhaust apparatus of the prior art.

[Best Embodiment of Invention]

First, one embodiment of a vacuum exhaust apparatus according to this invention will be described with reference to the drawings of Fig.1 to Fig.5, in which a multi-stage dry vacuum pump is used as a main pump.

The multi-stage dry vacuum pump is schematically shown in these figures, In the embodiment of the vacuum exhaust apparatus 10 of Fig.1, pairs of rotors R_1 , R_2 , R_3 , R_4 , R_5 and R_6 are driven by an electric motor 22 are arranged in a main body 21 of a multi-stage dry vacuum pump 20 (main pump). And an inlet port 23 is arranged in an upper wall of the left end of the main body 21. It communicates with a rotor chamber of the rotor R_1 . An exhaust pipe 25 provided

with a silencer 26 is connected to an outlet portion 24 connected to a rotor chamber of the rotor R_6 of the last stage. Further, a check valve 28 is connected through a pipe 27 to the silencer 26. The check valve 28 permits gas to flow only in the direction toward the atmosphere. An auxiliary pump 30 which is smaller in
5 the throughput than the main pump, is connected to the outlet portion 24.

Next, operation of this embodiment will be described.

With the drive of the motor 22, the rotors R_1 , R_2 , R_3 , R_4 , R_5 and R_6 are rotated to exhaust gas. The gas is transported from the respective rotor chambers towards the downward side, in order. A vacuum processing chamber
10 (not shown) connected to the inlet port 23 is exhausted. The pressure of the outlet portion 24 of the last stage is nearest to the atmosphere.

According to this invention, the outlet portion 24 is exhausted to a low pressure by the drive of the auxiliary pump 30. Thus, the load to the rotor of the last stage for exhaust is greatly reduced. And the consumed electric power of
15 the motor 22 can be greatly smaller than the prior art.

Fig.2 shows one modification of the vacuum exhaust apparatus 10 according to the embodiment of this invention. The parts which correspond to those in Fig.1, are denoted by the same reference numerals, the detailed descriptions of which will be omitted.

20 According to this embodiment, the outlet portion 24 of the last stage of the main pump 20' is connected to an exhaust pipe 25 through an opening of a main body 21. The silencer 26 is arranged in the exhaust pipe 25 which is further connected through a pipe 27 to a check valve 28, and is connected to the atmosphere. A pipe 31 is connected in parallel with the pipe 25, which is
25 connected to an auxiliary pump 30. An outlet port of the auxiliary pump 30 is connected through a pipe 32 to the atmosphere side of the check valve 28. Also in this embodiment, the energy conservation effect can be obtained similarly to the embodiment of Fig.1.

Further, since the auxiliary pump 30 is connected in parallel with the
30 exhaust pipe 25 and check valve 28, much amount of the gas is flowed through

the exhaust pipe 25, even through there occurs some trouble in the auxiliary pump 30. Thus, performance of the main pump 20' can be maintained.

Fig. 3 shows another modification of a vacuum exhaust apparatus 10 according to the embodiment of the invention.

5 According to this embodiment, an auxiliary pump 30 is connected in parallel with the check valve 28 through pipes 31 and 32. It is clear that the same effect as that of the embodiment of Fig. 2 can be obtained by this embodiment.

Fig. 4 and Fig.5 show modifications of the vacuum exhaust apparatus 10 of Fig.1 and Fig.2, respectively. According to these modifications, other outlet
10 portions 24' and 24" are arranged at the middle stages of the main pumps 20A and 20B different from the outlet portion 24 of the last stage. The auxiliary pump 30' is connected to the outlet portion 24' or 24".

The pressure of the middle stage is decreased in the main pumps 20A and 20B. The load of the rotor of the middle stage for exhaustion can be reduced.
15 Thus, the consumed power of the motor 22 can be reduced more than the prior art.

In the above embodiments, the rotors R_1 , R_2 , R_3 , R_4 , R_5 and R_6 all are equal to each other in size. Instead, the sizes of the rotors may be smaller towards the latter stage. It is evident that the consumed power can be smaller
20 than that of the above embodiments.

Further, the dry vacuum pump is not limited to the multi-stage Roots-type dry vacuum pump, but it may be, for example, a screw type or crew type. The same effect can be obtained also by them.

Next, construction of the check valve 28 used in the embodiment will be
25 described referring to Fig.6.

The check valve 28 is provided with a housing 40, a valve chamber 44, an annular valve seat 45, a ball valve body 46 able to seat on and be separated from, the valve seat 45 and a stopper 47. The housing 40 consists of an upper cylindrical body 41 positioned at the atmosphere side and a lower cylindrical
30 body 42 positioned at side of the main pump 40. The valve chamber 44 is

formed between the upper cylindrical body 41 and the lower cylindrical body 42. The valve seat 45 is formed at the lower end of the lower cylindrical body 42. The stopper 47 is formed on the lower end of the upper cylindrical body 41 for regulating lift of the ball valve body 46 to a predetermined height.

5 An annual sealing 48 is interposed between the contacting surfaces of the upper and lower cylindrical bodies 41 and 42. They are fixed to each other by plural bolt members. Thus, they are air-tightly formed as one body. The ball valve body 46 consists of hollow stainless ball. It is covered with thin rubber film. According to the embodiment, the self-weight of the ball valve body 46 is equal
10 to about 50 grams. When the pressure of the inlet side of the check valve 28 becomes about 700Pa beyond the atmosphere, the ball valve body 46 is so designed as to be lifted upwards.

The stopper 47 is constituted by four nails projected inwardly from the lower end of the upper cylindrical body 41 at the angular pitches of 90 degrees.
15 The ball valve body 46 is stopped by the stopper 47. The gas is flowed through the spaces between the nails 47 towards the atmosphere.

The check valve 28 has low resistance to the gas flow. It can be opened by a little pressure rise of the inlet side. Accordingly, it can follow rapid pressure change. Generally in the positive displacement type used as the main pump 20,
20 the gas is pushed out from the pump chamber and reversed into the pump chamber, repeatedly. Accordingly, gas pressure in the outlet portion 24 is pulsatingly changing. When the amount of the sucked gas becomes little, the ball valve body 46 is repeatedly seated and separated on and from, the valve seat 45 with the pulsating change of the gas pressure. When the followability of
25 the ball valve body 46 is deteriorated, the ball valve body seats for little time. The inlet side is sometimes maintained opened towards the atmosphere. At that time, the pressure of the inlet of the auxiliary pump 30 does not come to be reduced.

In the embodiment, the valve body of the check valve 28 is the ball valve body 46 and the valve is opened and closed only by the self-weight of the ball.
30 The followability to the pulsating pressure is high.

However, when the rotational speed of the rotor of the main pump 20 is higher, the check valve cannot sometimes follow the pulsating pressure. For example, in a dry vacuum pump of the screw type, when the rotational speed of the rotor is under 3600 r.p.m., the check valve can perfectly follow the pulsating pressure. However, it cannot follow the pulsating pressure at the rotational speed of 6000r.p.m. The ball valve body does not become to seat on the valve seat 45 perfectly.

It is considered that the ball valve body 46 is pushed onto the valve seat 45 by a spring having small spring constant and so having good followability to the gas pressure. However, this method requires much pressure loss of exhaust gas line due to the spring force of the spring and so higher gas pressure to lift the ball valve body 46 for opening the valve. Or it is considered that the gas pressure of the outlet portion is more rapidly reduced by an auxiliary pump 30 of higher throughput. However, in this method, the consumed electric power is increased and the energy conservation effect is decreased.

To overcome the disadvantage of the above method, two check valves 28a and 28b are serially connected to each other as shown in the vacuum exhaust apparatus 10 of Fig.7. The number of the serially connected check valves is limited to the two. Three check valves may be connected serially to each other. Each of the check valves 28a and 28b is constructed similar to the check valve 28 of Fig.6 as shown in Fig.8.

In a vacuum exhaust apparatus 10, the screw type dry vacuum pump was used as the main pump 20. The rotor was rotated at the speed of 6000r.p.m. to exhaust the vacuum processing chamber. The check valves 28a and 28b were accurately operated, not influenced by the pulsating pressure of the outlet chamber of the screw type dry vacuum pump. The consumed power was reduced to about 70% of the case in which merely the screw type dry vacuum pump.

In a further modification of the embodiment, a connection between the first check valve 28a and the second check valve 28b is connected through a pipe 29

to a suction side of auxiliary pump 30 as shown in Fig.9 and Fig.10. Thus the outlet portion of the main pump can be more stably exhausted.

Fig.11 shows a schematic conduit arrangement of a vacuum exhaust apparatus 10 according to the other embodiment of this invention. The main valve 13 and a pressure gauge 19 for measuring vacuum pressure are connected to a pipe 12 connecting the vacuum processing chamber 1 with the main pump 20 constituted by a single dry vacuum pump. The check valve 28 is connected to the main pump 20 through the exhaust pipe 25. The auxiliary pump 30 is connected in parallel with the check valve 28. A dry vacuum pump is used for auxiliary pump 30. The throughput of the auxiliary pump 30 is equal to about 10% of that of the main pump 20. The check valve is the same as that used in Fig.6. It includes the ball valve body floatable in the valve chamber, which floats from the seat at the pressure higher by about 700Pa than the atmosphere, to open the valve. It seats onto the valve seat by the self-weight of it, to close the valve. A gas exhaust processing apparatus (not shown) is connected to the downside of the gas exhaust pipe 15.

A high vacuum exhaust pump such as a turbo-molecular pump may be connected to the upper streamside of the main pump 20.

In the embodiment of this invention, a positive displacement type dry vacuum pump of the Roots-type is used for the main pump 20. Of course, it is not limited to that type, but a claw type and a screw type may be used as the dry vacuum pump. A pump of low consumed electric power and effective construction is used for the auxiliary pump 30.

It is preferable that a pump has such construction that the volume of the exhaust gas decreases in compression process. Accordingly, a sliding vane type (Gede), a piston type, a diaphragm type (membrane type) and a scroll type are suitable. The pumping speed of the auxiliary pump 30 is suitably selected within the range of a few percentages to about 20% of the pumping speed of the main pump 20, in accordance with a necessary capacity of a vacuum exhaust apparatus 10.

Next, operations of the vacuum exhaust apparatus 10 according to the embodiment as above-constructed, will be described.

The vacuum processing chamber 1 is exhausted from the atmosphere to a predetermined vacuum level. While the main pump 20 is driven, the auxiliary
5 pump 30 is always driven. When the outlet side of the main pump 20 is not exhausted to the pressure lower than the atmosphere by the auxiliary pump 30 due to much exhaust gas from the main pump 20, the check valve 28 is opened, and the exhaust gas is discharged in the direction shown by letter a. The exhaust of the vacuum processing chamber 1 processes, and so the inlet
10 pressure of the main pump 20 decreases. Accordingly, the gas amount decreases at the outlet port 24 of the main pump 20.

When the gas flow of the outlet side of main pump 20 starts to become less than atmosphere by the exhaust action of the auxiliary pump 30, it starts to become pulsating. The check valve 28 is repeatedly opened and closed.
15 However, the check valve 28 of the embodiment has the construction which is highly followable to the pulsating gas flow. Accordingly, the vacuum exhaust apparatus 10 of this embodiment can be driven with high reliability.

When the gas pressure of outlet side of main pump 20 becomes less than the atmosphere, the check valve 28 is perfectly closed and hereafter the gas
20 does not flow in the direction shown by the arrow a, but flows only in the direction shown by the arrow shown by the arrow b, by the exhaust action of the auxiliary pump 10. Thus the outlet pressure of the main pump 20 starts to be reduced and the reverse gas flow into the main pump 20 is reduced. Accordingly the consumed electric pressure of the main pump 20 decreases.

25 When the exhaust gas amount of the main pump 20 is so much that the check valve 28 is opened, the auxiliary pump 30 is not so useful. The total consumed electric power of the vacuum exhaust apparatus 10 including the consumed electric power of the main pump 20 and that of the auxiliary pump 30 is larger than the case that the auxiliary pump 30 is not driven.

30 However, for example, the volume of the vacuum processing chamber 1 is

less than 100 liters in most cases of semiconductor manufacturing equipment. The time when the outlet pressure of the main pump 20 reaches the pressure at which the auxiliary pump 20 becomes useful, is equal to a few minutes. Accordingly, the above energy loss is negligible in view of the energy
5 conservation.

Fig .12 shows the characteristics of the consumed electric power (the consumed electric power of the main pump 20 plus that of the auxiliary pump) to the inlet pressure of the main pump 20.

In the vacuum exhaust apparatus, the auxiliary pump 30 of the pumping
10 speed $1.8 \text{ m}^3/\text{Hr}$ is connected to the latter stage (the outlet side) of the main pump 20 of the pumping speed $150\text{m}^3/\text{Hr}$. The main pump 20 is the pump of the energy conservation type in which the throughput of the last stage is so designed as to be equal to 25% of that of the first stage. In Fig.12, a dot-dash line (· - · - · -) shows the case that the auxiliary pump 30 is not attached.

15 The solid line shows the case that the auxiliary pump 30 and the check valve 28 are arranged. The horizontal axis (inlet pressure) represents logarithm scale.

Consumed electric power is steeply decreased below the pressure of 1kPa with the auxiliary pump 30 as shown in Fig.12. Consumed electric power of the
20 main pump 20 without the auxiliary pump 30 is equal to 1.35kW on the ultimate pressure. That of the main pump 20 with the auxiliary pump 30 is equal to 0.32kw on the ultimate pressure. Energy conservation rate or consumed electric power reduction rate of about 76 % is obtained by the auxiliary pump 30. At the inlet pressure 400Pa of the main pump 20, the consumed electric power of the
25 main pump 20 without the auxiliary pump 30 is equal to 1.4kw. That of the main pump 20 with the auxiliary pump 30 is equal to 0.67kw. The energy conservation rate is equal to about 52%.

With the rise of the pumping speed of the auxiliary pump 30, the pressure at which the consumed electric power of main pump 20 starts to decrease,
30 moves rightwards in Fig.12 from about 1kPa or to the higher inlet pressure.

Accordingly, the pressure range which the energy conservation is effective, can be widened. However, the consumed electric power of the auxiliary pump 30 increases with the pumping speed and the energy conservation effect is reduced.

5 Generally in the vacuum exhaust system for the semiconductor manufacturing equipment, a small amount of the process gas is flowed into the vacuum processing chamber, maintaining a predetermined pressure, to treat film forming process or the like. At that case, the inlet pressure of the main pump 20 is equal to 1500Pa at highest, and so the object of the invention can be achieved by the fact that the energy conservation effect can be obtained in the range of
10 inlet pressure of less than about 3000 Pa.

Fig.13 considers that a multi-stage Roots-type dry vacuum pump as main pump is connected to the latter stage of a turbo-molecular pump. The relationship between the pumping speed ratio and the consumed electric power ratio is shown in Fig.13, where main pumps and auxiliary pumps different from
15 each other in pumping speed are differently combined with each other. The inlet pressure of the main pump is equal to 400Pa. The pumping speed ratio represents the ratio of the pumping speed of the auxiliary pump to that of the main pump. The consumed electric power ratio represents the ratio of the consumed electric power with the auxiliary pump, to that without the auxiliary
20 pump.

Accordingly, consumed electric power 100% means that there is no effect by the auxiliary pump. The consumed electric power with the auxiliary pump represents the total of the consumed electric powers of the main pump 20 and
25 auxiliary pump. The consumed electric power without auxiliary pump means that of the main pump.

It will be understood from Fig.13 that the consumed electric power ratio decreases with the raise of the pumping speed ratio and so the energy conservation effect rises with that. And it will be understood that the reduction
30 rate of the consumed electric power ratio tends to decrease near the pumping

speed ratio 3%. The reason will be described in later. From the above, it will be understood that the energy conservation effect can be sufficiently obtained by an auxiliary pump of a pumping speed lower than 3% of that of the main pump 20, at the inlet pressure 400Pa of the main pump 20. In the embodiment of this invention, the pumping speed ratio of the auxiliary pump to the main pump 20 is equal to 1.2%. Accordingly it fulfills the above requirement.

As above described, the inlet pressure of the main pump 20 at which the energy conservation effect starts to be obtained, moves towards a higher pressure with the rise of the pumping speed ratio of the auxiliary pump to the main pump. However, the consumed electric power of the auxiliary pump 30 increases with the pumping speed. The total consumed electric power of the main pump 20 and the auxiliary pump 30 becomes larger than the consumed electric power without the auxiliary pump, under the above condition. The details will be described with reference to Fig.14 and Fig.15.

Fig.14 shows a typical relationship between the pumping speed and the consumed electric power, of a vacuum pump usable as the auxiliary pump. Fig.15 shows the relationship between the pumping speed ratio of the pumping speed of the auxiliary pump having the characteristic shown in Fig.14 and the pumping speed 150m³/hr of a dry vacuum pump as the main pump at the inlet pressure 400Pa of the main pump 20, and the consumed electric power. In Fig.15, a dot-dash line (·-·-·-) shows the consumed electric power of only the main pump 20. It decreases steeply with the rise of the pumping speed ratio of the auxiliary pump to main pump 20. It converges to the power corresponding to the mechanical loss of the main pump 20 over the pumping speed ratio 4%. The dotted line (·····) represents the relationship between the consumed electric power and the pumping speed ratio of the auxiliary pump having the characteristic of Fig.14, to the main pump 20. The total consumed electric power of auxiliary pump and the main pump 20 is represented by the solid line in Fig.15. Or it is the total consumed electric power of the vacuum exhaust apparatus.

It will be understood from the solid line of Fig.15 that the consumed electric

power is smallest at the pumping speed ratio about 3% of the auxiliary pump to the main pump 20.

With reference to Fig.12 and Fig.15, the energy conservation rate 50% can be obtained at the pumping speed ratio 1.2% or 9.4% of the auxiliary pump to the main pump 20 and at the inlet pressure 400Pa of the main pump 20.

However, the auxiliary pump of the pumping speed ratio 9.4% is larger in size than the auxiliary pump 30 of the pumping speed ratio 1.2% according to the embodiment. The former is disadvantageous in the arrangement space and energy for manufacturing the pump. Accordingly, it is preferable to select the auxiliary pump of the pumping speed ratio less than 3%. Thus, it is possible to obtain a vacuum exhaust apparatus of totally high energy conservation rate. On the other hand, the auxiliary pump of the pumping speed ratio over the ratio 3% reduces the energy conservation effect.

As shown by the solid line in Fig.12, the consumed electric power is almost horizontal or constant within the inlet pressure range below 10Pa. That means that the compression work in the pump chamber is negligibly small at such a low outlet pressure of the main pump 20 and the consumed electric power is equal to the mechanical loss of the main pump 20.

The consumed electric power gradually increases with the gradual increase of the inlet pressure of main pump 20. That means that the compression work of the last stage of the main pump 20 which is the work for pushing the reverse flow back, comes to become remarkable. The consumed electric power of the main pump 20 is proportional to the outlet pressure. Accordingly, in order to obtain the low consumed electric power shown by the solid line in Fig.12, the capacity to exhaust the gas to the low outlet pressure is required for the auxiliary pump.

The suction gas amount to rise the consumed electric power by 10% from the consumed electric power on the ultimate pressure is set. The measured pressure of the auxiliary pump is equal to 6.5kPa to 20kPa. When the auxiliary pump has not the capacity to exhaust the gas to the pressure of less than the

20kPa, the consumed electric power which is equal to the mechanical loss of the main pump 20, cannot be obtained on the ultimate pressure.

Fig.16 shows the pumping speed characteristics of the vacuum exhaust apparatus of the embodiment. The solid line shows that the auxiliary pump is used. The dot-dash line shows that the auxiliary pump is not used. The pumping speed of the vacuum exhaust apparatus with auxiliary pump is higher by 10% than that without the auxiliary pump.

The ultimate pressure of the apparatus with the auxiliary pump is improved to 1Pa from 2Pa in comparison with that of the apparatus without the auxiliary pump. That means that reverse gas flow amount decreases with the decrease of the outlet pressure of the main pump 20 and so the volume efficiency has been risen. The effective energy conservation can be obtained as the whole vacuum exhaust apparatus. With the auxiliary pump, the consumed electric power can be reduced, and further the pumping speed and the ultimate pressure can be improved.

While the preferred embodiments of the vacuum exhaust apparatus have been described, variations thereto will occur to those skilled in the art within the scope of the present inventive concepts which are delineated by the following claims.

For example, a single dry vacuum pump is used as the main pump 20 in the above embodiment. Plural multi-stage Roots-type dry vacuum pumps may be serially connected. Such a composite type pump may be used as the main pump 20. Further in the above embodiment, the auxiliary pump is connected to the outlet side of the single main pump 20. However, plural main pumps 20A, 20B and 20C as shown in Fig.17 may be connected in parallel with each other. The outlet sides of the main pumps are connected to one auxiliary pump 30. In the shown example, check valves 28a, 28b and 28c are connected to the respective main pumps 20A to 20C. Further valves 11a, 11b and 11c are connected between the auxiliary pump 30 and the check valves 28a, 28b and 28c, and the main pumps 20A, 20B, and 20C are connected to different vacuum

processing chambers, respectively. Suction gas amount of the auxiliary pump 30 changes with the number of the driven main pump 20A 20B and 20C. The pumping speed (rotational speed) of the auxiliary pump 30 may be changed in accordance with the number of the driven main pumps 20A to 20C.

5 A driving method of the vacuum exhaust apparatus of this invention will be described in detail, with reference to the vacuum exhaust apparatus of Fig.11.

When the vacuum processing chamber 1 is exhausted from the atmosphere by the vacuum exhaust apparatus 10, first the auxiliary pump 30 starts to be driven and the main valve 13 is opened to start the exhaust. When it
 10 has been confirmed by the pressure gauge 19 that the vacuum of the chamber 1 has reached 10^4 Pa, the main pump 20 is started and driven to the rotational speed, for example, 3600r.p.m. to exhaust the vacuum processing chamber 1 to the pressure 1Pa. Fine particles are prevented to fly high up in the vacuum processing chamber 1 by the above driving method. Thus the slow exhaust can
 15 be effected by the drive of only the auxiliary pump 30, without the small diameter by-pass valve connected in parallel with the main valve. After the vacuum has reached the pressure 1Pa, the vacuum exhaust apparatus 10 is sequentially and stationary driven. At that time, the exhaust gas flow is little and the check valve 28 closes. The exhaust is effected only by the auxiliary pump 30. Thus
 20 consumed electric power of the vacuum exhaust apparatus 10 is reduced and noise is suppressed.

In Fig.11, nominal outside diameter of the exhaust pipe 15 is 40A. The exhaust amount of the auxiliary pump and sequentially that of the main pump 20 are small. Accordingly it can be substituted with a pipe of nominal outside
 25 diameter 10A (bore 10mm $\approx$ 3 /8 inches). The pipe of the above bore can be bent for manufacturing and so the manufacturing cost of the pipe arrangement can be reduced.

There has been described the driving method of the vacuum exhaust apparatus with the reference to the embodiment. Of course, this invention is not
 30 limited to the above embodiment, but various modifications will be possible on

the basis of the technical concept of the invention.

For example, in the above embodiment, after the vacuum processing chamber has reached the predetermined pressure by the auxiliary pump, the main pump is started and the rotor is rotated at the rotational speed 3600 r.p.m.

- 5 However, before the vacuum processing chamber reaches the predetermined pressure, the rotational speed of the main pump 20 may be so controlled as to be gradually increased from the low rotational speed of the small throughput in accordance with the vacuum degree of the vacuum processing chamber, by the inventor.

- 10 Thus the rapid pressure change on the start of the main pump 20 can be avoided. Thus the main pump 20 can be started not so as to impart load to the auxiliary pump.

[Industrial Applicability]

- 15 According to the vacuum exhaust apparatus and the drive method of the vacuum exhaust apparatus, energy conservation can be more greatly achieved by a simple construction than the prior art and the slow exhaust can be easily effected.

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[Scope of Demand]

1. A vacuum exhaust apparatus characterized in that said apparatus includes a main pump, a check valve permitting gas to flow only in the direction
5 towards the atmosphere, connected to the outlet side of said main pump and an auxiliary pump of smaller throughput than that of said main pump connected in parallel with said check valve at the outlet side of said main pump and said check valve includes a ball valve body floatable in a valve chamber, said valve body floats up by an exhaust gas pressure of said main pump to open the valve and it seats on a
10 valve seat by self-weight under said exhaust gas pressure, to close the valve.

2. A vacuum exhaust apparatus according to claim 1 in which said ball valve body consists of a hollow metal ball and is coated with rubber.

3. A vacuum exhaust apparatus according to claim 1 in which said check valve consists of plural members serially connected to each other.

15 4. A vacuum exhaust apparatus according to claim 3 in which a space between said plural members is connected to the suction side of said auxiliary pump.

5. A vacuum exhaust apparatus according to claim 1 in which at least one of pump chambers at the latter stage of said main pump is smaller than the pump
20 chambers of the former stage of said main pump so that the throughput of the latter stage is smaller than that of the former stage.

6. A vacuum exhaust apparatus according to claim 1 in which said auxiliary pump is driven at the pumping speed lower than 3% of that of said main pump at the inlet pressure 400Pa of said main pump.

25 7. A vacuum exhaust apparatus according to claim 1 in which a plurality of said main pumps are connected in parallel with each other and the inlet side of said auxiliary pump is connected to the respective outlets of said main pump.

8. A drive method for driving a vacuum exhaust apparatus characterized in that said apparatus includes a main pump connected to a vacuum processing
30 chamber, a check valve permitting gas to flow only in the direction towards the

atmosphere, connected to the outlet side of said main pump and an auxiliary pump of smaller throughput than that of said main pump connected in parallel with said check valve at the outlet side of said main pump, whereby, when said vacuum processing chamber is exhausted from the atmosphere or from near the atmosphere, first said auxiliary pump is driven and after said vacuum processing chamber has reached a predetermined pressure, said main pump is driven.

9. A drive method for driving a vacuum exhaust apparatus characterized in that said apparatus includes a main pump connected to a vacuum processing chamber, a check valve permitting gas to flow only in the direction towards the atmosphere, connected to the outlet side of said main pump and an auxiliary pump of smaller throughput than that of said main pump connected in parallel with said check valve at the outlet side of said main pump, whereby, when said vacuum processing chamber is exhausted from the atmosphere or from near atmosphere, first said auxiliary pump is driven and before said vacuum processing chamber reaches a predetermined pressure, said main pump is started to be driven at the lower speed or the lower pumping speed and the rotational speed is raised in accordance with the pressure of the vacuum processing chamber.

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