

SPECIFICATION

TITLE OF THE INVENTION

APPARATUS FOR GENERATING MINUTE GAS FOAMS

5

UNDER SELF-SUCTION

BACKGROUND OF THE INVENTION

1. Field of the invention:

This invention relates generally to an apparatus for
10 generating minute gas foams under self-suction. More
particularly, it relates to a self-suction type foam
generating apparatus wherein gas is sucked through a supply
duct under negative pressure generated by rotation of a
rotor, and divided into minute foams for effective
15 gas-liquid contact.

2. Description of the Related Art:

There are typically two types of foam generators. A
first one is a pressure-feed type foam generator wherein
gas is fed under positive pressure from outside, as
20 disclosed in JP-A-56(1981)-133018 for example. A second
one is a self-suction type foam generator wherein gas is
sucked in under negative pressure generated by rotation
of a rotor disposed inside, as disclosed in JP-A-
61(1986)-35932 for example. Both types of foam generators
25 may be advantageously utilized for cleaning exhaust gas
(e.g. exhaust gas from a semiconductor manufacturing
apparatus) by contact with an absorbent liquid (e.g.

water).

Specifically, the pressure-feed type foam generator disclosed in JP-A-56(1981)-133018 comprises a liquid container for accommodating an absorbent liquid, a rotor
5 immersed in the liquid, and a supply means connected to the rotor for supplying gas into the rotor. The rotor is downwardly open and upwardly closed. The supply means includes a piping and a pressurizing means such as a pump. The gas supplied into the rotor exits out from the lower
10 open end of the rotor, whereupon the gas is divided into minute foams by the rotation of the rotor.

On the other hand, the self-suction type foam generator disclosed in JP-A-61(1986)-35932 comprises a liquid container for accommodating a liquid, a supply duct
15 partially immersed in the liquid and having a downwardly open end for supplying a gas, a rotor disposed in the liquid in facing relation to the open end of the supplying duct, and a drive means for driving the rotor. The rotor includes an upwardly closed cylinder having an upper wall
20 or lid formed with a plurality of radially extending vanes. The cylinder also has a circumferential wall formed with a plurality of vertically extending ridges. When the rotor is driven by the drive means to rotate, a radial flow is generated in the clearance between the rotor and the
25 supply duct. Such a radial flow results in generation of a negative pressure which sucks the gas through the supply duct. The gas thus sucked is crushed or divided by the

rotating vanes and ridges into minute foams before dispersing the gas into the liquid.

The self-suction type foam generator is superior to the pressure-feed type foam generator in that it requires
5 no means for pressurizing the gas, which may result in added cost and added consumption of energy in addition to the need for separate maintenance. However, the conventional self-suction type foam generator has been found to be still disadvantageous for the following reasons.

10 As previously described, a negative pressure is generated in the clearance between the rotor and the supply duct. However, unless the dimension of the clearance is strictly defined, it is not possible to obtain an appropriate degree of negative pressure as required for
15 effectively sucking down the gas through the supply duct. This is partly due to the fact that complicated flows actually take place in the clearance because the liquid must enter radially inward into the clearance before flowing radially outward. In practice, a suitable degree
20 of negative pressure may be obtained only if the clearance is adjusted to fall in tolerance of $\pm 0.5\text{mm}$ from a predetermined value. For this reason, a high degree of precision is called for with respect to production of components and assembly thereof, which results in added
25 cost.

SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to provide a self-suction type foam generating apparatus which can be assembled without strict positional accuracy with respect to a rotor and a supply duct while providing stable formation of minute gas foams.

According to the present invention, there is provided an apparatus for generating minute gas foams under self-suction comprising a liquid container for accommodating a liquid, a supply duct partially immersed in the liquid and having a downwardly open end for supplying a gas, a rotor disposed in the liquid in facing relation to the open end of the supplying duct and driven to rotate for sucking the gas and for dispersing the gas into the liquid as minute foams, and a drive means for driving the rotor, characterized that the rotor includes a boss, a hollow cylinder which is open at least upwardly and surrounds the boss, and a plurality of vanes extending radially in the hollow cylinder.

Preferably, the hollow cylinder may be open both upwardly and downwardly for allowing upward passage of the liquid through the rotor, so that the generated foams can be uniformly mixed with or dispersed into the liquid.

Preferably, the hollow cylinder may have a reinforcing bottom wall which is formed with a plurality of openings. Further, each of the vanes may have a radially inner edge connected to the boss, and a radially outer edge connected

to the hollow cylinder.

In one embodiment of the present invention, each of the vanes is contained in a vertical plane passing through a central axis of the rotor.

5 In another embodiment of the present invention, each vane is inclined relative to a vertical plane passing through a central axis of the rotor in a manner such that an upper edge of the vane is ahead of a lower edge of the vane with respect to the rotational direction of the rotor.

10 In this case, the angle of inclination of each vane should be preferably no more than 45° .

An upper edge of each vane may be flush with an upper edge of the hollow cylinder. Alternatively, the upper edge of each vane may project beyond an upper edge of the
15 hollow cylinder.

The drive means may be disposed under the liquid container. Alternatively, the drive means may be disposed above the liquid container.

Other objects, features and advantages of the present
20 invention will become apparent from the following description of the preferred embodiment given with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

25 Fig. 1 is a schematic view showing a self-suction type foam generating apparatus embodying the present invention.

Fig. 2a is a plan view showing an example of rotor to be incorporated in the foam generating apparatus.

Fig. 2b is a sectional view of the rotor shown in Fig. 2a.

5 Fig. 3a is a plan view showing another example of rotor to be incorporated in the foam generating apparatus.

Fig. 3b is a sectional view of the rotor shown in Fig. 3a.

10 Fig. 4a is a graph showing the performance of the rotor shown in Figs. 2a and 2b with respect to maximum suction force.

Fig. 4b is a graph showing the performance of the rotor shown in Figs. 2a and 2b with respect to fluctuations of suction force.

15 Fig. 5a is a graph showing the performance of the rotor shown in Figs. 3a and 3b with respect to maximum suction force.

Fig. 5b is a graph showing the performance of the rotor shown in Figs. 3a and 3b with respect to fluctuations of
20 suction force.

Fig. 6 is a front view showing a conventional rotor.

Fig. 7a is a graph showing the performance of the conventional rotor with respect to maximum suction force.

Fig. 7b is a graph showing the performance of the
25 conventional rotor with respect to fluctuations of suction force.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred embodiments of the present invention will be specifically described with reference to the accompanying drawings.

5 Referring first to Figs. 1, 2a and 2b of the drawings, a self-suction type foam generating apparatus generally represented by reference numeral 1 may be utilized for removing harmful gaseous substances from exhaust gas G of a semiconductor manufacturing apparatus (not shown). The
10 foam generating apparatus 1 comprises a liquid container 2 which is upwardly closed by a lid plate 9. The container 2 accommodates a suitable liquid L, typically water, for absorbing the harmful gaseous substances from the exhaust gas G supplied as minute foams, as described hereinafter.
15 The lid plate 9 is penetrated by a supply duct 3 in a vertically suspending state. The supply duct 3 is partially immersed in the liquid L and has an open lower end 4. The supply duct 3 also has an upper inlet 8 for entry of the exhaust gas G. The lid plate 9 is provided
20 with an outlet 10 for discharging the exhaust gas G after removal of the harmful substances. Though not shown, the container 2 may be provided with means for supplementing or circulating the liquid L.

The container 2 has a bottom wall 2a which is penetrated
25 by a vertical drive shaft 6 of a motor M via a known seal device 7. The drive shaft 6 carries a rotor 5 inside the container 2 in alignment with the supply duct 3. The rotor

5 faces the lower open end 4 of the supply duct 3 with a predetermined clearance. The rotor 5 is driven by the motor M to rotate at a speed of 1,000~2,000 rpm for example.

Alternatively, the rotor 5 may be driven by a motor 5 which is located by the lid plate 9. In this case, the motor has a drive shaft extending downward through the supply duct 3.

As shown in Figs. 2a and 2b, the rotor 5 includes a central boss 21 for fitting on the drive shaft 6 of the motor M (Fig. 1), and a hollow cylinder 22 concentrically surrounding the central boss 21. A plurality of vanes 23 extend radially within the cylinder 22 at an upper portion thereof at an equal angular spacing. Specifically, each of the vanes 23 has a radially inner end connected to the central boss 21, and a radially outer end connected to the cylinder 22, thereby connecting between the boss 21 and the cylinder 22. The number of the vanes 23 may be 3~8 for example. In this embodiment, each of the vanes 23 is contained in a vertical plane passing through the central axis 25 of the rotor 5.

The bottom of the rotor 5 is provided with a reinforcing disk 24 which connects between the boss 21 and the cylinder 22. The disk 24 is formed with a plurality of openings 26 for allowing upward passage of the liquid L (see Fig. 1) through the hollow cylinder 22 (i.e., through the rotor 5).

In operation, the rotor 5 incorporating the plurality of vanes 23 rotates at high speed to work as a centrifugal pump for generating a radially outward flow between the supply duct 3 and the rotor 5. Such a radial flow results in a pressure drop (negative pressure) which causes the exhaust gas G to be sucked down through the supply duct 3 while causing the liquid L to be sucked up through the hollow cylinder 22 of the rotor 5. Therefore, the exhaust gas G and the liquid L flow together radially outward between the supply duct 3 and the rotor 5 while mixing with each other. At this time, further, the exhaust gas G is sheared and/or crushed by the vanes 23 rotating at high speed and/or by the vortices generated at the rear side of the vanes 23. As a result, the exhaust gas G is divided into minute foams before dispersing into the body of the liquid L wherein the harmful gaseous substances contained in the exhaust gas G (the minute foams thereof) are removed by absorption into the liquid L.

Figs. 3a and 3b show another embodiment of rotor 5. As shown, the rotor 5 of this embodiment is similar to the one shown in Figs. 2a and 2b but differs therefrom only in that each of the vanes 23 is inclined relative to a vertical plane containing the central axis 25 of the rotor 5. The orientation of the vane inclination is such that the upper edge of the vane 23 is located ahead of the lower edge with respect to the rotational direction X of the rotor 5. The angle of the vane inclination may be preferably

no more than 45° (30° in the illustrated embodiment).

When rotated, the rotor 5 sucks up the liquid L through the hollow cylinder 22 due to the generation of a negative pressure between the supply duct 3 and the rotor 5, as previously described. However, if too much liquid L is sucked up per unit time, this may hinder the sucking-down of the exhaust gas G through the supply duct 3. Thus, it is necessary to adjust the amount of liquid L to be sucked up through the hollow cylinder 22 to such a degree that a suitable amount of exhaust gas G can still be sucked down per unit time. In other words, it is critically important to prevent the sucking-up of the liquid L from predominating over the sucking-down of the exhaust gas G.

Indeed, there are various ways for realizing this. One way is to properly adjusting the dimensions and number of the vanes 23. Another way is to properly adjust the configuration of the vanes 23 including the inclination thereof.

According to the embodiment shown in Figs. 3a and 3b, each of the vanes 23 is inclined to suitably limit the sucking-up of the liquid L though it still allows partial sucking-up of the liquid L. Thus, the exhaust gas G continues to be appropriately sucked down through the supply duct 3 for mixture with and dispersion into the sucked-up portion of the liquid L.

In either of the embodiments shown in Figs. 2a, 2b, 3a and 3b, each of the vanes 23 has an upper edge which

is flush with the upper edge of the hollow cylinder 22. However, the upper edge of the vane 23 may slightly retreats below or projects above the upper edge of the hollow cylinder 22 as long as the vane 23 is located at an upper portion of the rotor 5 in order for the rotor 5 to work as a centrifugal pump. If the vane 23 projects above the upper edge of the cylinder 22, the pumping function of the rotor 5 is enhanced.

Further, in any of the foregoing embodiments, the height of the hollow cylinder 22 may be 0.2~2.0 times, preferably 0.4~1.2 times, its diameter. The height of each vane 23 may be preferably 0.1~0.8 times the height of the hollow cylinder 22. The diameter of the hollow cylinder 22 may be 0.3~3.0 times, preferably 1.0~3.0 times, the diameter of the supply duct 3 at its lower open end 4. In the case where the hollow cylinder 22 is diametrically larger than the supply duct 3, the lower open end 4 of the supply duct 3 may be preferably flanged, as shown in Fig. 1.

The rotor 5 may be made of any suitable material such as a metal or a resin. In view of chemical resistance and ease of forming, the rotor 5 may be preferably made of a resin material such as polyvinyl chloride, polyethylene or polypropylene.

Next, actual examples of the present invention will be described together with comparative examples (referred to as "Comparison").

(Example 1)

In accordance with the embodiment shown in Figs. 2a and 2b, a rotor 5 was prepared which included a hollow cylinder 22 (Inner Diameter: 126mm, Outer Diameter: 132mm, Height: 71mm), six vanes 23 (Height or Width: 25mm, Length: 39mm), and a central boss 21 (Inner Diameter: 22mm). All of these elements were made of polyvinyl chloride. Each of the vanes 23 was contained in a vertical plane containing the central axis 25 of the rotor, and had an upper edge which was flush with the upper edge of the hollow cylinder 22. The boss 21 was mounted on a drive shaft 6 of a motor M. The drive shaft 6 was made of stainless steel.

On the other hand, the motor drive shaft 6 was mounted to penetrate a bottom wall 2a of a liquid container 2 (Inner Diameter: 400mm, Height: 825mm) via a seal device 7. The container 2 was made of transparent polyvinyl chloride. The rotor 5 was arranged in the container 2 so that the upper edge of the hollow cylinder 22 was located 125mm above the bottom wall 2a. Water as a liquid L was accommodated in the container 2, and a supply duct 3 (Inner Diameter: 60mm) was mounted to penetrate through a lid plate 9 of the container 2 to be partially immersed in the water L. A lower open end 4 of the supply duct was positioned directly above the rotor 5 and flanged to have an outer diameter of 135mm. The mounting height of the supply duct 3 was adjusted to vary the clearance between the lower open end 4 of the supply duct 3 and the rotor 5 in a range of

10~40mm.

Under the above conditions, nitrogen gas was supplied through an upper inlet 8 of the supply duct 3 while the rotor 5 was driven by the motor M to rotate at varying speeds (50Hz: 1,480rpm, 55Hz: 1,630rpm, 60Hz: 1,780rpm) under inverter control. As previously described, the clearance between the supply duct 3 and the rotor 5 was varied to see how the suction or negative pressure generated by the rotor 5 varies at each different speed as the clearance varies. The suction force was measured by connecting a U-pipe (not shown) to the supply duct 3 via a nozzle (not shown) and by reading the water head of the U-pipe. The performance of the rotor 5 was determined by evaluating the magnitude of the measured negative pressure (suction force) and the fluctuations of the pressure (stability). In this test, nitrogen gas was used instead of actual exhaust gas because the purpose of the test was only to see the performance of the rotor 5.

The results of the test are represented in Figs. 4a and 4b. As can be observed in the graph of Fig. 4a, a slightly positive pressure resulted when the clearance between the supply duct 3 and the rotor 5 was no more than 10mm, but a progressively larger negative pressure was obtained as the clearance increased up to a certain level. For instance, when the rotor 5 rotated at a speed of 1,780rpm, the negative pressure became maximum when the clearance was 26.5mm. However, as observed in the graph

of Fig. 4b, when the clearance increased beyond 26.5mm, the negative pressure fluctuated in an undesirably wide range. Thus, it may be concluded that the clearance in this example should preferably lie in a range of 17.4~26.5mm. Further, just for information, it should be mentioned that when the rotor 5 rotated at a speed of 1,780rpm with a clearance of 26.5mm, the amount of nitrogen gas sucked down was 100dm³/min.

(Example 2)

10 In accordance with the embodiment shown in Figs. 3a and 3b, a rotor 5 was prepared which included a hollow cylinder 22 (Inner Diameter: 126mm, Outer Diameter: 132mm, Height: 71mm), six vanes 23 (Height or Width: 25mm, Length: 39mm), and a central boss 21 (Inner Diameter: 22mm). All
15 of these elements were made of polyvinyl chloride. Each of the vanes 23 was inclined at an angle of 30° relative to a vertical plane containing the central axis 25 of the rotor, and had an upper edge which was flush with the upper edge of the hollow cylinder 22. The boss 21 was mounted
20 on a drive shaft 6 of a motor M. The drive shaft 6 was made of stainless steel.

On the other hand, the motor drive shaft 6 was mounted to penetrate a bottom wall 2a of a liquid container 2 (Inner Diameter: 400mm, Height: 825mm) via a seal device 7. The
25 container 2 was made of transparent polyvinyl chloride. The rotor 5 was arranged in the container 2 so that the upper edge of the hollow cylinder 22 was located 125mm above

the bottom wall 2a. Water as a liquid L was accommodated in the container 2, and a supply duct 3 (Inner Diameter: 60mm) was mounted to penetrate through a lid plate 9 of the container 2 to be partially immersed in the water L.

5 A lower open end 4 of the supply duct was positioned directly above the rotor 5 and flanged to have an outer diameter of 135mm. The mounting height of the supply duct 3 was adjusted to vary the clearance between the lower open end 4 of the supply duct 3 and the rotor 5 in a range of
10 10~40mm.

Under the above conditions, the performance of the rotor 5 was evaluated in the same manner as in Example 1. The results are represented in Figs. 5a and 5b.

As can be observed in the graph of Fig. 5a, a
15 progressively larger negative pressure was obtained at each different rotational speed (50Hz: 1,480rpm, 55Hz: 1,630rpm, 60Hz: 1,780rpm) of the rotor 5 as the clearance between the supply duct 3 and the rotor 5 increased from 10mm to 31.7mm. Further, the inclined vanes 23 generated
20 a larger negative pressure at each different rotational speed and at each different clearance than the vertical vanes of Example 1. In this Example 2, when the rotor 5 rotated at a speed of 1,780rpm with a clearance of 24.5mm, the amount of nitrogen gas sucked down was 120dm³/min.

25 On the other hand, as observed in the graph of Fig. 5b, the fluctuation of the suction force (negative pressure) was 138mmH₂O when the rotor 5 rotated at a high

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speed of 1,780rpm (60Hz) with a small clearance of 10mm though the suction force does not fluctuate much at each lower speed (50Hz: 1,480rpm, 55Hz: 1,630rpm) at each different clearance. However, when the clearance
5 increased to no less than 11.8mm, the fluctuation of the suction force dropped to a practical level of no more than 100 mmH₂O even with respect to the high rotational speed of 1,780rpm (60Hz). Thus, it may be concluded that the applicable range of the clearance in this example is
10 11.8~31.7mm which is much wider than the applicable range obtained in Example 1.

(Comparison 1)

For comparison, use was made of a conventional rotor
50 which had such a structure as shown in Fig. 6.
15 Specifically, the rotor 50 included a cylinder 71 (Outer Diameter: 120mm) which is closed upwardly and downwardly, ten radial vanes 73 fixed on the top wall 72 (lid) of the cylinder 71, and twenty vertical ridges 74 fixed on the circumferential wall of the cylinder 71. The rotor was
20 mounted on a drive shaft 6 of a motor M (see Fig. 1).

On the other hand, the motor drive shaft 6 was mounted to penetrate a bottom wall 2a of a liquid container 2 (Inner Diameter: 400mm, Height: 825mm) via a seal device 7. The container 2 was made of transparent polyvinyl chloride.
25 The rotor 50 was arranged in the container 2 so that the upper edge of each vane 73 was located 125mm above the bottom wall 2a. Water as a liquid L was accommodated in

the container 2, and a supply duct 3 (Inner Diameter: 60mm) was mounted to penetrate through a lid plate 9 of the container 2 to be partially immersed in the water L. A lower open end 4 of the supply duct was positioned directly
5 above the rotor 50 and flanged to have an outer diameter of 135mm. The mounting height of the supply duct 3 was adjusted to vary the clearance between the lower open end 4 of the supply duct 3 and the rotor 50 in a range of 0~10mm.

Under the above conditions, the performance of the
10 rotor 50 was evaluated in the same manner as in Example 1. The results are represented in Figs. 7a and 7b.

As can be observed in the graphs of Fig. 7a and 7b, a meaningful negative pressure was generated only at a high rotational speed of 1,780rpm (60Hz:) in a narrow clearance
15 range of 4~5mm though the generated pressure, either negative or positive, was relatively stable. Thus, it may be concluded that there is a great limitation on the setting of the clearance and the rotational speed of the rotor.

20 The present invention being thus described, it is apparent that the same may be varied in many ways. Such variations should not be regarded as a departure from the spirit and scope of the present invention, and all such modifications as would be obvious to those skilled in the
25 art are intended to be included within the scope of the following claims.

CLAIMS



1. An apparatus for generating minute gas foams under self-suction comprising:

5 a liquid container (2) for accommodating a liquid (L);

 a supply duct (3) partially immersed in the liquid (L) and having a downwardly open end (4) for supplying a gas (G);

10 a rotor (5) disposed in the liquid (L) in facing relation to the open end (4) of the supplying duct (3) and driven to rotate for sucking the gas (G) and for dispersing the gas (G) into the liquid (L) as minute foams; and

 a drive means (M) for driving the rotor (5);

15 characterized that the rotor (5) includes a boss (21), a hollow cylinder (22) which is open at least upwardly and surrounds the boss (21), and a plurality of vanes (23) extending radially in the hollow cylinder (22).

20 2. The apparatus according to claim 1, wherein the hollow cylinder (22) is open both upwardly and downwardly.

3. The apparatus according to claim 2, wherein the hollow cylinder (22) has a reinforcing bottom wall (24) which is
25 formed with a plurality of openings (26).



4. The apparatus according to any one of claims 1 to 3, wherein each of the vanes (23) has a radially inner edge connected to the boss (21), and a radially outer edge connected to the hollow cylinder (22).

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5. The apparatus according to any one of claims 1 to 3, wherein each of the vanes (23) is contained in a vertical plane passing through a central axis of the rotor (5).

10 6. The apparatus according to any one of claims 1 to 3, wherein each vane (23) is inclined relative to a vertical plane passing through a central axis of the rotor (5) in a manner such that an upper edge of the vane is ahead of a lower edge of the vane with respect to the rotational
15 direction (X) of the rotor (5).

7. The apparatus according to claim 6, wherein the angle of inclination of each vane (23) is no more than 45° .

20 8. The apparatus according to any one of claims 1 to 3, wherein an upper edge of each vane (23) is flush with an upper edge of the hollow cylinder (22).

9. The apparatus according to any one of claims 1 to 3,
25 wherein an upper edge of each vane (23) projects beyond an upper edge of the hollow cylinder (22).

10. The apparatus according to any one of claims 1 to 3,
wherein the drive means (M) is disposed under the liquid
container (2).

5 11. The apparatus according to any one of claims 1 to 3,
wherein the drive means (M) is disposed above the liquid
container (2).



ABSTRACT

APPARATUS FOR GENERATING MINUTE GAS FOAMS UNDER SELF-SUCTION

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An apparatus for generating minute gas foams under self-suction comprises a liquid container (2) for accommodating a liquid (L), a supply duct (3) partially immersed in the liquid (L) and having a downwardly open end (4) for supplying a gas (G), a rotor (5) disposed in the liquid (L) in facing relation to the open end (4) of the supplying duct (3) and driven to rotate for sucking the gas (G) and for dispersing the gas (G) into the liquid (L) as minute foams, and a drive means (M) for driving the rotor (5). The rotor (5) includes a boss, a hollow cylinder which is open at least upwardly and surrounds the boss, and a plurality of vanes extending radially in the hollow cylinder.

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(Fig. 1)