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Apparatus trapping an exhaust material from a substrate-processing process and apparatus for processing a substrate including the trapping apparatus

Abstract

An apparatus for trapping an exhaust material from a substrate-processing process includes: a cyclone configured to provide the exhaust material with a swirling flow, wherein the exhaust material is discharged from the substrate-processing process using a reaction gas; an atomization module for providing the cyclone with a mist to convert the exhaust material into a powder through a wet oxidation reaction; and a collector configured to collect the powder.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION

(1) This application claims priority under 35 USC § 119 to Korean Patent Application No. 10-2021-0116935, filed on Sep. 2, 2021 in the Korean Intellectual Property Office (KIPO), the disclosure of which is incorporated by reference herein in its entirety.

TECHNICAL FIELD

(2) Exemplary embodiments of the present inventive concept relate to an apparatus and a method of trapping an exhaust material from a substrate-processing process and apparatus for processing a substrate including the trapping apparatus. More particularly, exemplary embodiments of the present inventive concept relate to an apparatus and a method of trapping an exhaust gas discharged from a reaction chamber configured to process a semiconductor substrate, and an apparatus for processing a substrate including the trapping apparatus.

DISCUSSION OF THE RELATED ART

(3) Generally, a reaction chamber for fabricating a semiconductor device may process a substrate using a reaction gas. Typically, an exhaust material may be discharged from the reaction chamber during a substrate-processing process. For example, the exhaust material may be discharged from the reaction chamber through an exhaust line with a vacuum provided from a vacuum pump.

(4) According to related arts, a trapping apparatus such as a scrubber may generate a physical phase transition reaction of the exhaust material to form a powder. The powder may be accumulated on an inner surface of the exhaust line so that the exhaust line may become clogged. Thus, it may be required to periodically remove the powder from the exhaust line so that it may be unclogged or prevented from becoming clogged.

(5) The powder removal from the exhaust line may be performed after stopping the reaction chamber. Thus, an operating ratio of the reaction chamber may be lowered and a decrease in a productivity of the semiconductor device may occur. Further, because the scrubber and the vacuum pump may be stopped, operational safety of the trapping apparatus may be reduced. Furthermore, there may be an increased probability of exposing a worker to the powder, which may result in a negligent accident.

(6) In addition, the formation of the powder may be dependent upon the physical phase transition reaction. Thus, a component among components in the exhaust material, which may not belong to conditions of the physical phase transition reaction, might not be trapped.

SUMMARY

(7) According to an exemplary embodiment of the present inventive concept, an apparatus for trapping an exhaust material from a substrate-processing process includes: a cyclone configured to provide the exhaust material with a swirling flow, wherein the exhaust material is discharged from the substrate-processing process using a reaction gas; an atomization module for providing the

cyclone with a mist to convert the exhaust material into a powder through a wet oxidation reaction; and a collector configured to collect the powder.
(8) According to an exemplary embodiment of the present inventive concept, an apparatus for processing a substrate includes: a reaction chamber configured to process the substrate by using a reaction gas; a vacuum pump configured to provide the reaction chamber with vacuum to discharge an exhaust material from the reaction chamber; a cyclone connected to the reaction chamber and the vacuum pump and configured to provide the exhaust material with a swirling flow; an atomization module providing the cyclone with a mist to convert the exhaust material into a powder through a wet oxidation reaction; and a collector configured to collect the powder from the cyclone.
(9) According to an exemplary embodiment of the present inventive concept, a method of trapping an exhaust material from a substrate-processing process includes: providing the exhaust material with a mist such that the exhaust material is converted into a powder through a wet oxidation reaction, wherein the exhaust material is discharged from the substrate-processing process; and collecting the powder in a collector.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) The above and other features of the present inventive concept will become more apparent by describing in detail exemplary embodiments thereof, with reference to the accompanying drawings, in which;
(2) FIG. **1** is a view illustrating an apparatus for trapping an exhaust material from a substrate-processing process according to an exemplary embodiment of the present inventive concept;
(3) FIG. **2** is an enlarged view illustrating a cyclone and a collector of the trapping apparatus in FIG. **1**;
(4) FIG. **3** is a perspective view illustrating an inner structure of the cyclone in FIG. **2**;
(5) FIGS. **4**A, **4**B, and **4**C are cross-sectional views illustrating the cyclone in FIG. **3**;
(6) FIG. **5** is a plan view illustrating the cyclone in FIG. **3**;
(7) FIG. **6** is a cross-sectional view illustrating a cyclone in according to an exemplary embodiment of the present inventive concept;
(8) FIG. **7** is a plan view illustrating the cyclone in FIG. **6**;
(9) FIG. **8** is a cross-sectional view illustrating a cyclone according to an exemplary embodiment of the present inventive concept;
(10) FIG. **9** is a plan view illustrating the cyclone in FIG. **8**;
(11) FIG. **10** is a view illustrating an apparatus for processing a substrate including the trapping apparatus in FIG. **1**; and
(12) FIG. **11** is a flow chart illustrating a method of trapping an exhaust material from a substrate-processing process using the trapping apparatus in FIG. **1**.
DETAILED DESCRIPTION OF THE EMBODIMENTS
(13) Hereinafter, exemplary embodiments of the present inventive concept will be described in detail with reference to the accompanying drawings.
(14) FIG. **1** is a view illustrating an apparatus for trapping an exhaust material from a substrate-processing process according to an exemplary embodiment of the present inventive concept. FIG. **2** is an enlarged view illustrating a cyclone and a collector of the trapping apparatus in FIG. **1**. FIG. **3** is a perspective view illustrating an inner structure of the cyclone in FIG. **2**. FIGS. **4**A to **4**C are cross-sectional views illustrating the cyclone in FIG. **3**, and FIG. **5** is a plan view illustrating the cyclone in FIG. **3**. In FIG. **1**, a full line may indicate a fluid flow and a dotted line may indicate a control signal.

(15) A trapping apparatus according to an exemplary embodiment of the present inventive concept may convert an exhaust material, which may be discharged from a substrate-processing process using a reaction gas (e.g., a reaction chamber), into a powder through a wet oxidation reaction. The trapping apparatus may then trap the powder. The exhaust material may include a non-reacted gas, which is among the reaction gas, non-reacted with a substrate, byproducts that are generated by a reaction between the reaction gas and the substrate, etc. For example, the non-reacted gas might not have reacted with the substrate. The trapping apparatus according to an exemplary embodiment of the present inventive concept may induce the wet oxidation reaction of the non-reacted gas to convert the non-reacted gas into the powder. However, the trapping apparatus according to an exemplary embodiment of the present inventive concept may be applied to the byproducts, which are not limited to the non-reacted gas. The substrate-processing process may include processes for manufacturing a semiconductor device using the reaction gas. For example, the substrate-processing process may include a deposition process, a diffusion process, an etching process, an ashing process, etc.
(16) Referring to FIGS. **1** to **5**, the trapping apparatus **100** according to an exemplary embodiment of the present inventive concept may include a cyclone **110**, an atomization module **120** and a collector **190**.
(17) The cyclone **110** may be configured to receive the exhaust material discharged from the reaction chamber. The cyclone **110** (or, e.g., a funnel) may provide the exhaust material with a downwardly swirling flow to perform a centrifugation of components in the exhaust material. In an exemplary embodiment of the present inventive concept, the cyclone **110** may include a cyclone body **112**, an inlet port **114**, an outlet port **116** and a plurality of nozzles **118**.
(18) The cyclone body **112** may have an empty inner space configured to receive the exhaust material. The cyclone body **112** may include a cylindrical portion **112***a* and a circular conical portion **112***b*. The cylindrical portion **112***a* may be connected to the reaction chamber. The cylindrical portion **112***a* may have a closed upper surface. The circular conical portion **112***b* may be extended from a lower end of the cylindrical portion **112***a*. The circular conical portion **112***b* may have gradually decreased diameters toward a downward direction. For example, the diameter of the circular conical portion **112***b* may gradually decrease in the downward direction. An opening **112***c* may be formed at a lower end of the circular conical portion **112***b*.
(19) A protection layer **11**I may be coated on an inner surface of the cyclone body **112**. The protection layer **111** may include, for example, a hydrophobic material having a chemical-resistance. The hydrophobic protection layer **11**I may prevent the powder, which may be converted from the exhaust material by the wet oxidation reaction, from adhering to the inner surface of the cyclone body **112**. Further, the hydrophobic protection layer **111** may protect the inner surface of the cyclone body **112** from a corrosive component in the exhaust material. In an exemplary embodiment of the present inventive concept, the protection layer **111** may include Teflon, polychlorotrifluoroethylene (CTFE), fluorinated ethylene propylene (FEP), perfluoroalkoxy alkane (PFA), etc.; however, the present inventive concept not limited thereto.
(20) The inlet port **114** may be arranged at an upper portion of a side surface of the cyclone body **112**. The inlet port **114** may be connected to the reaction chamber. Thus, the exhaust material may be introduced into the cyclone body **112** through the inlet port **114**. For example, the inlet port **114** may be formed at the upper portion of the side surface of the cyclone body **112** along a tangential direction.
(21) The outlet port **116** may vertically enter into the cyclone body **112** through a central portion of the upper surface of the cyclone body **112**. For example, the outlet port **116** may have a lower end higher than the lower end of the cylindrical portion **112***a*. For example, a gap may be between the lower end of the outlet port **116** and the lower end of the cylindrical portion **112***a*. A residual gas, which may not be converted into the powder from the exhaust material, may be discharged through the outlet port **116**. A filter **116***a* is configured to prevent a solid component in the exhaust material

from being discharged through the outlet port **116**, and may be arranged in the outlet port **116**.
(22) The nozzles **118** may be arranged on the inner surface of the cyclone body **112**. The nozzles **118** may receive a mist from the atomization module **120**. The nozzles **118** may inject the mist into the cyclone body **112**. For example, the nozzles **118** may inject the mist to the exhaust material in the cyclone body **112** to induce the wet oxidation reaction of the exhaust material.
(23) In the cyclone body **112**, the exhaust material may be swirled around a center of the cyclone body **112**. To uniformly inject the mist to the swirled exhaust material, the nozzles **118** may be horizontally spaced apart from each other by a gap. For example, the nozzles **118** may be horizontally spaced apart from each other by a gap in a central portion of the cyclone body **112**. For example, nozzles **118** on the inner surface of the cyclone body **112** may be horizontally arranged to be spaced apart from each other by a uniform gap on a horizontal plane. As another example, each nozzle **118** may directly face an opposing nozzle **118**.
(24) Further, exhaust material may be downwardly swirled in the cyclone body **112**. To more facilitate the wet oxidation reaction of the exhaust material, the nozzles **118** may be vertically spaced apart from each other by a gap. For example, the nozzles **118** may be vertically spaced apart from each other by a substantially uniform gap. The vertically arranged nozzles **118** may receive the mist through a mist passage **119** vertically formed along the inner surface of the cyclone body **112**. For example, each of the nozzles **118** may be inclined in the downward direction to the center of the cyclone body **112**. Thus, the mist from the nozzles **118** may be downwardly injected toward the center of the cyclone body **112**.
(25) In addition, the nozzles **118** may not be oriented toward the center of the cyclone body **112**. For example, the nozzles **118** may be arranged in a direction slanted to a direction toward the center of the cyclone body **112**. As another example, the nozzles **118** may be arranged in the swirling direction of the exhaust material or in a direction opposite to the swirling direction of the exhaust material. The nozzles **118** may be arranged along the horizontal direction.
(26) Referring to FIG. **4**B, the nozzles **118** may be vertically arranged on the entire inner surface of the cylindrical portion **112***a* of the cyclone body **112**. At least one of the nozzles **118** may be positioned under the lower end of the outlet port **116** so that the mist may directly inject to a lower region of the cylindrical portion **112***a* under the outlet port **116**. When an amount of the mist injected from the nozzles **118** may be too much, a part of the mist might not be involved in the wet oxidation reaction of the exhaust material. In this case, the part of the mist may be discharged through the outlet port **116**. Because the outlet port **116** may be connected to a vacuum pump and a scrubber, moistures in the mist may damage the vacuum pump and the scrubber.
(27) To prevent the damages of the vacuum pump and the scrubber, as shown in FIG. **4**A, the nozzles **118** may be arranged on only an upper region of the inner surface of the cylindrical portion **112***a* of the cyclone body **112**. For example, a lowermost nozzle **118** among the nozzles **118** may be positioned higher than the lower end of the outlet port **116**. Thus, the mist might not be directly injected to the lower region under the outlet port **116**. However, when an optimal amount of the mist injected from the nozzles **118** may be controlled so that most of the mist may be involved in the wet oxidation reaction of the exhaust material, it might not be required to limit the position of the nozzles **118** in FIG. **4**A.
(28) In addition, referring to FIG. **4**C, the nozzles **118** may be vertically arranged on the inner surface of the cylindrical portion **112***a* of the cyclone body **112**. An outlet port **116***b* may enter into the circular conical portion **112***b* and may pass through the lower end of the cylindrical portion **112***a*. Thus, the lowermost nozzle **118** of the plurality of nozzles **118** in the cylindrical portion **112***a* may be positioned higher than a lower end of the outlet port **116***b* in the circular conical portion **112***b*.
(29) FIG. **6** is a cross-sectional view illustrating a cyclone according to an exemplary embodiment of the present inventive concept, and FIG. **7** is a plan view illustrating the cyclone in FIG. **6**.
(30) Referring to FIGS. **6** and **7**, a mist passage **119***a* in an exemplary embodiment of the present

inventive concept may be formed at an outer surface of the cyclone body **112**. A plurality of nozzles **118***a* may enter into the cyclone body **112** through a wall of the cyclone body **112** from the mist passage **119***a*. Thus, a lower end of each of the nozzles **118***a* may be positioned in the cyclone body **112**. For example, an upper end of each of the nozzles **118***a* may be positioned in the mist passage **119***a*. In addition, the lower end of the nozzle **118***a* might not protrude beyond the inner surface of the cyclone body **112**.
(31) FIG. **8** is a cross-sectional view illustrating a cyclone according to an exemplary embodiment of the present inventive concept, and FIG. **9** is a plan view illustrating the cyclone in FIG. **8**.
(32) Referring to FIGS. **8** and **9**, a mist passage **119***b* of the cyclone **110** according to an exemplary embodiment of the present inventive concept may be formed in a wall of the cyclone body **112**. For example, the mist passage **119***b* may be vertically extended in the wall of the cyclone body **112**. For example, the mist passage **119***b* may be formed in the wall of the cylindrical portion **112***a*. A plurality of nozzles **118***b* may be extended from the mist passage **119***b* into the cyclone body **112**. In addition, a lower end of the nozzle **118***b* might not protrude beyond the inner surface of the cyclone body **112**.
(33) Referring again to FIG. **1**, the atomization module **120** may be configured to provide the cyclone **110** with the mist. The atomization module **120** may include an atomizer **130**, a water supply module **160**, a compressed gas supply module **170**, a density transmitter **140** and a density controller **150**.
(34) The water supply module **160** may be configured to supply water to the atomizer **130**. The compressed gas supply module **170** may be configured to supply a compressed gas to the atomizer **130**. The atomizer **130** may form the mist from the water and the compressed gas. The atomizer **130** may provide the cyclone **110** with the mist. For example, the atomizer **130** may supply the mist to the nozzles **118**.
(35) The water supply module **160** may include a water tank **162**, a flow transmitter **164** and a pump **166**. The water tank **162** may be configured to store the water. The flow transmitter **164** may be arranged between the water tank **162** and the atomizer **130** to measure a flux of the water supplied to the atomizer **130** from the water tank **162**. The pump **166** may be arranged between the water tank **162** and the flow transmitter **164** to forcibly pump the water from the water tank **162** to the atomizer **130**. However, when the water in the water tank **162** has pressure supplied to the atomizer **130**, the water supply module **160** might not include the pump **166**.
(36) The compressed gas supply module **170** may include a gas tank **172**, a pressure regulator **174** and a valve **176**. The gas tank **172** may be configured to store the compressed gas. The pressure regulator **174** may measure a pressure of the compressed gas supplied from the gas tank **172** to the atomizer **130**. The valve **176** may be configured to control a flow of the compressed gas supplied from the gas tank **172** to the atomizer **130**. In an exemplary embodiment of the present inventive concept, the compressed gas may include air and/or an inert gas. The inert gas may include, for example, nitrogen, argon, etc., but the present inventive concept not limited thereto.
(37) The density transmitter **140** may be arranged between the atomizer **130** and the cyclone **110**. The density transmitter **140** may measure a density of the mist generated from the atomizer **130**.
(38) The density controller **150** may be arranged between the water supply module **160** and the atomizer **130** and between the compressed gas supply module **170** and the atomizer **130**. Thus, the water from the water supply module **160** and the compressed gas from the compressed gas supply module **170** may be supplied to the atomizer **130** through the density controller **150**. Mist data including data of the flux of the water measured by the flow transmitter **164**, data of the pressure of the compressed gas measured by the pressure regulator **174**, data of the density of the mist measured by the density transmitter **140** may be transmitted to the density controller **150**. The density controller **150** may control the density of the mist generated from the atomizer **130** in accordance with the mist data.
(39) The collector **190** may be connected with the lower end of the cyclone **110** via a trapping pipe

180. In addition, the trapping pipe **180** may be integrally formed with the lower end of the cyclone body **112**; however, the present inventive concept is not limited thereto.
(40) The powder converted from the exhaust material by the wet oxidation reaction may be collected in the collector **190** through the trapping pipe **180**. For example, the collector **190** may be connected to a lower end of the trapping pipe **180** and may be detachable from the lower end of the trapping pipe **180**. For example, the collector **190** may be detachably connected to the lower end of the trapping pipe **180** via a pipe coupler **192**. However, the collector **190** and the trapping pipe **180** may be connected with each other by other detachable type connection structures, and the present inventive concept is not limited to the pipe coupler **192**. In addition, the collector **190** may be directly and detachably connected to the lower end of the cyclone **110**.
(41) A gate valve **182** may be installed on the trapping pipe **180**. The gate valve **182** may be configured to open and close the trapping pipe **180**. In addition, other valves configured to open and close the trapping valve **180** may be used in place of the gate valve **182**.
(42) To remove the powder in the collector **190**, the gate valve **182** may be closed. The collector **190** may be detached from the trapping pipe **180** using the pipe coupler **192**. After removing the powder in the collector **190**, the collector **190** may then be connected to the lower end of the trapping pipe **180** using the pipe coupler **192**.
(43) A swing gate **184** may be arranged between the lower end of the cyclone **110** and the gate valve **182**. The swing gate **184** may prevent a backward flow of the powder in the collector **190** toward the cyclone **110** through the trapping pipe **180**. In addition, other valves configured to prevent the backward flow of the powder may be used in place of the swing gate **184**.
(44) A pressure gauge **186** may be installed on the trapping pipe **180**. The pressure gauge **186** may measure a pressure in the trapping pipe **180** to check if a leak is present in the trapping pipe **180**.
(45) In an exemplary embodiment of the present inventive concept, the operation for providing the exhaust material with the mist to form the powder and the operation for collecting the powder in the collector **190** may be performed during processing of the substrate in the reaction chamber in real time.
(46) For example, when the collector **190** is fully filled with the powder so that the collector **190** may not collect additional powder, the gate valve **182** may be closed. The collector **190** may be detached from the trapping pipe **180**. The powder in the collector **190** may then be removed. Because the gate valve **182** may be closed, an inner pressure of the reaction chamber connected to the cyclone **110**, for example, the vacuum may be maintained. Thus, the operation for removing the powder in the collector **190** may be performed during processing of the substrate in the reaction chamber in real time without stopping the reaction chamber. Further, the operation for providing the exhaust material with the mist to form the powder may be performed regardless of the operation for removing the powder in the collector **190**. The powder generated while collector **190** is detached from the trapping pipe **180**, may be collected in the trapping pipe **180**. Thus, when the collector **190** is connected to the trapping pipe **180** and the gate valve **182** is then be opened, the powder in the trapping pipe **180** may be collected in the collector **190**.
(47) FIG. **10** is a view illustrating an apparatus for processing a substrate including the trapping apparatus in FIG. **1**. In FIG. **10**, a full line may indicate a fluid flow and a dotted line may indicate a control signal.
(48) Referring to FIG. **10**, a substrate-processing apparatus **200** according to an exemplary embodiment of the present inventive concept may include a reaction chamber **210**, the trapping apparatus **100**, a vacuum pump **220** and a scrubber **230**. The trapping apparatus **100** may include the elements in FIG. **1**. Thus, any further descriptions with respect to the trapping apparatus **100** that may be assumed to be redundant may be omitted herein for brevity. In addition, like reference numerals may refer to like elements, and thus repetitive descriptions may be omitted.
(49) The reaction chamber **210** may be connected with the trapping apparatus **100** through a first vacuum line **240**. The trapping apparatus **100** may be connected with the vacuum pump **220**

through a second vacuum line **250**. Thus, the vacuum pump **220** may provide the reaction chamber **210** with the vacuum through the trapping apparatus **100**.

(50) The first vacuum line **240** may be connected to the cyclone **110** of the trapping apparatus **100**. For example, the first vacuum line **240** may be connected to the inlet port **114** of the cyclone **110**. The second vacuum line **250** may be connected to the cyclone **110** of the trapping apparatus **100**. For example, the second vacuum line **250** may be connected to the outlet port **116** of the cyclone **110**. Thus, the vacuum generated from the vacuum pump **220** may be introduced into the cyclone **110** through the second vacuum line **250** and the outlet port **116**. The vacuum in the cyclone **110** may be introduced into the reaction chamber **210** through the inlet port **114** and the first vacuum line **240**.

(51) The reaction chamber **210** may be configured to process the substrate using the reaction gas. For example, the reaction chamber **210** may include a deposition chamber, a diffusion chamber, an etching chamber, an ashing chamber, etc.

(52) For example, when the reaction chamber **210** includes the deposition chamber, a layer may be deposited on the substrate using a deposition gas in the reaction chamber **210**. For example, to deposit a TiN layer, the deposition gas introduced into the reaction chamber **210** may include TiCl.sub.4, NH.sub.3, 4ClF.sub.3, etc. A tiny part of the deposition gas may react with the substrate to form the TiN layer on the substrate. In addition, most of the deposition gas might not react with the substrate. Most of the deposition gas may be discharged from the reaction chamber **210**.

(53) For example, a gas discharged from the reaction chamber **210** may have following chemical reactions in a pipe between the reaction chamber **210** and the vacuum pump **220**.

TiCl.sub.4(g)+NH.sub.3(g).fwdarw.TiCl*x*(NH*y*)*z*(s)

TiCl.sub.4(g)+4ClF.sub.3(g).fwdarw.TiF.sub.4(s)+8ClF(g)

(54) It can be noted that solid byproducts such as TiClx(NHy)z, TiF.sub.4, etc., may be formed in the pipe from the above chemical reactions. The solid byproducts may be accumulated on the inner surface of the pipe to clog the pipe.

(55) Here, the solid byproducts configured to clog the pipe may be generated from the gaseous TiCl.sub.4. For example, TiCl.sub.4 may be a main ingredient for generating the solid byproducts in the pipe.

(56) The trapping apparatus **100** may trap TiCl.sub.4 using the wet oxidation reaction. For example, when TiCl.sub.4 may be introduced into the cyclone **110**, the atomization module **120** may inject the mist to TiCl.sub.4. TiCl.sub.4 and the mist may have a following wet oxidation reaction.

TiCl.sub.4(g)+2H.sub.2O(aq).fwdarw.TiO.sub.2(s)+4HCl(g)

TiCl.sub.4(g)+O.sub.2(g).fwdarw.TiO.sub.2(s)+2Cl.sub.2(g)

(57) TiCl.sub.4 may be converted into a solid TiO.sub.2 by the wet oxidation reaction. For example, it can be noted that TiCl.sub.4 which may be the main ingredient for generating the solid byproducts, among the gases discharged from the reaction chamber **210** may be converted into the powder-shaped TiO.sub.2 by the wet oxidation reaction.

(58) The wet oxidation reaction may be readily generated at about a room temperature. When TiCl.sub.4 may be reacted with the moisture in the mist, heat of about 279 KJ/mol may be generated from the reaction. Further, when TiCl.sub.4 may be reacted with oxygen, heat of about 182 KJ/mol may be generated from the reaction. When a maximum residence time of the exhaust material in the cyclone **110** may be about 10 seconds, the wet oxidation reaction may be generated at a temperature of about 31° C. to about 38.5° C.

(59) For example, when the reaction gas includes a halogen metal compound such as WF.sub.6, CuCl.sub.2, etc., the halogen metal compound may be converted into a powder through following wet oxidation reactions.

WF.sub.6+3H2O.fwdarw.WO.sub.3+6HF

CuCl.sub.2+2H.sub.2O.fwdarw.Cu(H.sub.2O).sub.2Cl.sub.2

(60) For example, when the reaction gas includes DCS (SiH.sub.2Cl.sub.2, dichlorosilane),

NH.sub.3, NH.sub.4Cl as byproducts may be generated. SiH.sub.2Cl.sub.2 and NH.sub.4Cl may be converted into a powder through following wet oxidation reactions.
NH.sub.4Cl(s).fwdarw.NH.sub.4Cl(aq).fwdarw.NH.sub.4.sup.+(aq)+Cl.sup.−(aq)
SiH.sub.2Cl.sub.2+H.sub.2O.fwdarw.[H.sub.2SiO].sub.n+HCl
(61) According to an exemplary embodiment of the present inventive concept, the trapping apparatus may convert the main ingredient, which may generate the solid byproducts and is among the exhaust material discharged in the deposition process, into the solid powder by the wet oxidation reaction. For example, the exhaust material may be converted into the powder by the wet oxidation reaction regardless of phase transition conditions of the exhaust material.
(62) The functions of the trapping apparatus may be applied to the diffusion process, the etching process, the ashing process, etc., to convert a main ingredient, which may generate the solid byproducts, into a solid powder by the wet oxidation reaction. The main ingredient is among the exhaust material discharged in the diffusion process, the etching process, the ashing process, etc.
(63) The powder may be collected in the collector **190** through the trapping pipe **180**. For example, the operation for providing the exhaust material with the mist to form the powder and the operation for collecting the powder in the collector **190** may be performed in real time during processing of the substrate.
(64) The powder, which may be generated by the wet oxidation reaction in real time during processing of the substrate in the reaction chamber **210**, may be continuously collected in the collector **190**. When the collector **190** is fully filled with the powder, the gate valve **182** may be closed. The collector **190** may be detached from the trapping pipe **180**. The powder in the collector **190** may then be removed. Because the gate valve **182** may be closed, the inner pressure of the reaction chamber **210** connected to the cyclone **110**, for example, the vacuum may be maintained. Thus, the operation for removing the powder in the collector **190** may be performed in real time during processing of the substrate without the stopping of the reaction chamber **210**.
(65) In addition, the residual gas, which may not be converted into the powder, among the exhaust material may be discharged through the outlet port **116**. Because the vacuum pump **220** may provide the cyclone **110** with the vacuum, the residual gas may be discharged through the outlet port **116** and the second vacuum line **250**.
(66) The scrubber **230** may be connected to the second vacuum line **250**. For example, the scrubber **230** may connected to the second vacuum line **250** through the vacuum pump **220**. However, the present inventive concept is not limited thereto. For example, the scrubber **230** may be directly connected to the second vacuum line **250**. The scrubber **230** may trap the residual gas discharged through the second vacuum line **250**.
(67) FIG. **11** is a flow chart illustrating a method of trapping an exhaust material from a substrate-processing process using the trapping apparatus in FIG. **1**.
(68) Referring to FIGS. **1**, **10** and **11**, in step ST**300**, the exhaust material discharged from the reaction chamber **210** may be introduced into the cyclone **110**. The exhaust material may be downwardly swirled in the cyclone **110**.
(69) In step ST**302**, the water supply module **160** may supply the water to the atomizer **130** through the density controller **150**. Further, the compressed gas supply module **170** may supply the compressed gas to the atomizer **130** through the density controller **150**.
(70) In step ST**304**, the flow transmitter **164** may measure the flux of the water. The measured flux of the water may then be transmitted to the density controller **150**.
(71) In step ST**306**, the pressure regulator **174** may measure the pressure of the compressed gas. The measured pressure of the compressed gas may then be transmitted to the density controller **150**.
(72) In step ST**308**, the atomizer **130** may form the mist from the water and the compressed gas.
(73) In step ST**310**, the density transmitter **140** may measure the density of the mist formed by the atomizer **130**. The measured density of the mist may then be transmitted to the density controller

150.

(74) In step ST**312**, the density controller **150** may control a density of a mist (e.g., a following mist) formed in the atomizer **130** based on the flux of the water, the pressure of the compressed gas, the density of the mist, etc. For example, the following mist may be a mist generated after the flux of the water, the pressure of the compressed gas, the density of the mist have been measured.

(75) In step ST**314**, the mist having the density controlled by the density controller **150** may be supplied to the nozzles **118** of the cyclone **110**.

(76) In step ST**316**, the nozzles **118** may inject the mist into the cyclone **110** to generate the wet oxidation reaction between the exhaust material and the mist. The exhaust material may then be converted into the powder by the wet oxidation reaction.

(77) In step ST**318**, the powder may be collected in the collector **190** through the trapping pipe **180**.

(78) In step ST**320**, the residual gas, which may not be converted into the powder, among the exhaust gas may be discharged through the outlet port **116**. The scrubber **230** may trap the residual gas. For example, the scrubber **230** may be connected to the outlet port **116** through the second vacuum line **250** and the vacuum pump **220**.

(79) In an exemplary embodiment of the present inventive concept, the step for providing the exhaust material with the mist to form the powder and the step for collecting the powder in the collector **190** may be performed in real time during processing of the substrate.

(80) In step ST**322**, when the collector **190** is fully filled with the powder so that the collector **190** may not collect the powder any more, the gate valve **182** may be closed.

(81) In step ST**324**, the collector **190** may be detached from the trapping pipe **180**. The powder in the collector **190** may then be removed. Because the gate valve **182** may be closed, the inner pressure of the reaction chamber **210** connected to the cyclone **110** may be maintained. Thus, the operation for removing the powder in the collector **190** may be performed in real time during processing of the substrate in the reaction chamber **210** without the stopping of the reaction chamber **210**.

(82) According to an exemplary embodiment of the present inventive concept, the mist may be provided to the exhaust material discharged from the substrate-processing process to generate the wet oxidation reaction between the exhaust material and the mist. Thus, the exhaust material may be changed into the powder regardless of phase transition conditions of the exhaust material. As a result, trapping efficiency of the exhaust material may be increased.

(83) Further, in an exemplary embodiment of the present inventive concept, the operation for providing the exhaust material with the mist to form the powder and the operation for collecting the powder in the collector may be performed in real time during processing of the substrate. Thus, a productivity of a semiconductor device may be increased by increasing an operating ratio of the reaction chamber. Therefore, it might not be required to stop the scrubber and the vacuum pump so that operational safety of the trapping apparatus may also be increased. Furthermore, a negligent accident may be prevented because a worker might not be exposed to the powder.

(84) The foregoing is illustrative of exemplary embodiments of the present inventive concept and is not to be construed as limiting of the present inventive concept. Although a few exemplary embodiments of the present inventive concept have been described, those of ordinary skill in the art will readily appreciate and understand that various modifications and changes in form and details may be made to the exemplary embodiments of the present inventive concept without materially departing from the spirit and scope of the present inventive concept. Accordingly, all such modifications and changes are intended to be included within the spirit and scope of the present inventive concept. In the claims, means-plus-function clauses are intended to cover the structures described herein as performing the recited function and not only structural equivalents but also equivalent structures. Therefore, it is to be understood that the foregoing is illustrative of exemplary embodiments of the present inventive concept and is not to be construed as being limited to the specific exemplary embodiments disclosed, and that modifications to the disclosed

exemplary embodiments, as well as other exemplary embodiments, are intended to be included within the spirit and scope of the present inventive concept.

Claims

1. An apparatus for trapping an exhaust material from a substrate-processing process, the apparatus comprising: a cyclone configured to provide the exhaust material with a swirling flow, wherein the exhaust material is discharged from the substrate-processing process using a reaction gas; an atomization module for providing the cyclone with a mist to convert the exhaust material into a powder through a wet oxidation reaction; and a collector configured to collect the powder, wherein the atomization module includes: an atomizer configured to form the mist; a water supply module configured to supply water to the atomizer and to measure a flux of the water supplied to the atomizer; a compressed gas supply module configured to supply a compressed gas to the atomizer and to measure a pressure of the compressed gas supplied to the atomizer; a density transmitter configured to measure a density of the mist provided from the atomizer to the cyclone; and a density controller configured to control the density of the mist formed by the atomizer based on data of the flux of water that received from the water supply module, data of pressure of compressed gas that is received from the compressed gas supply module, and data of the density of the mist that is received from the density transmitter.
2. The apparatus of claim 1, wherein the cyclone comprises: a cyclone body configured to provide the exhaust material with the swirling flow, wherein the cyclone body includes an opened lower end through which the powder passes; an inlet port connected to a side surface of the cyclone body and configured to introduce the exhaust material into the cyclone body; an outlet port entering into the cyclone body and configured to discharge a residual gas, which is not converted into the powder, among the exhaust material; and a first nozzle arranged on an inner surface of the cyclone body and configured to inject the mist provided from the atomization module into the cyclone body.
3. The apparatus of claim 2, wherein the cyclone further comprises a hydrophobic protection layer coated on the inner surface of the cyclone body.
4. The apparatus of claim 3, wherein the protection layer comprises Teflon, polychlorotrifluoroethylene (CTFE), fluorinated ethylene propylene (FEP) or perfluoroalkoxy alkane (PFA).
5. The apparatus of claim 2, wherein the cyclone body comprises: a cylindrical portion connected to the inlet port and the outlet port, and a circular conical portion connected to the cylindrical portion and the collector.
6. The apparatus of claim 5, wherein the first nozzle has a lower end positioned in the cylindrical portion.
7. The apparatus of claim 6, wherein the lower end of the first nozzle is positioned higher than a lower end of the outlet port.
8. The apparatus of claim 6, wherein the outlet port passes through the cylindrical portion and has a lower end positioned in the circular conical portion.
9. The apparatus of claim 6, wherein the outlet port has a lower end positioned in the cylindrical portion.
10. The apparatus of claim 2, wherein the first nozzle is of a plurality of nozzles arranged in at least one of a vertical direction or a horizontal direction.
11. The apparatus of claim 1, wherein the water supply module comprises: a water tank configured to store the water; and a flow transmitter configured to measure the flux of the water supplied from the water tank to the atomizer.
12. The apparatus of claim 11, wherein the water supply module further comprises a pump configured to pump the water from the water tank to the atomizer.

13. The apparatus of claim 1, wherein the compressed gas supply module comprises: a gas tank configured to store the compressed gas; and a pressure regulator configured to measure the pressure of the compressed gas supplied from the gas tank to the atomizer.
14. The apparatus of claim 1, wherein the collector is configured to be connected to a lower end of the cyclone and to be detached from the lower end of the cyclone.
15. The apparatus of claim 1, further comprising a trapping pipe connected a lower end of the cyclone and the collector and configured to allow a movement of the powder from the cyclone to the collector, wherein the collector is configured to be connected to a lower end of the trapping pipe and to be detached from the lower end of the trapping pipe.
16. The apparatus of claim 15, further comprising: a gate valve installed at the trapping pipe; a swing gate installed at the trapping pipe and between the lower end of the cyclone and the gate valve; and a pressure gauge arranged between the lower end of the cyclone and the swing gate.
17. An apparatus for processing a substrate, the apparatus comprising: a reaction chamber configured to process the substrate by using a reaction gas; a vacuum pump configured to provide the reaction chamber with vacuum to discharge an exhaust material from the reaction chamber; a cyclone connected to the reaction chamber and the vacuum pump and configured to provide the exhaust material with a swirling flow; an atomization module providing the cyclone with a mist to convert the exhaust material into a powder through a wet oxidation reaction; and a collector configured to collect the powder from the cyclone, wherein the atomization module includes: an atomizer configured to form the mist; a water supply module configured to supply water to the atomizer and to measure a flux of the water supplied to the atomizer; a compressed gas supply module configured to supply a compressed gas to the atomizer and to measure a pressure of the compressed gas supplied to the atomizer; a density transmitter configured to measure a density of the mist provided from the atomizer to the cyclone; and a density controller configured to control the density of the mist formed by the atomizer based on data of the flux of water that received from the water supply module, data of pressure of compressed gas that is received from the compressed gas supply module, and data of the density of the mist that is received from the density transmitter.
18. The apparatus of claim 17, wherein an operation of the atomization module and an operation of the collector are performed in real time during processing of the substrate in the reaction chamber.