(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
28 January 2016 (28.01.2016)

WIPO | PCT

(10) International Publication Number
WO 2016/014136 A1

(51) International Patent Classification:
H01L 21/205 (2006.01)

(21) International Application Number:
PCT/US2015/028352

(22) International Filing Date:
29 April 2015 (29.04.2015)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/027,051 21 July 2014 (21.07.2014) US
14/694,676 23 April 2015 (23.04.2015) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

(54) Title: CONDITIONING REMOTE PLASMA SOURCE FOR ENHANCED PERFORMANCE HAVING REPEATABLE ETCH AND DEPOSITION RATES

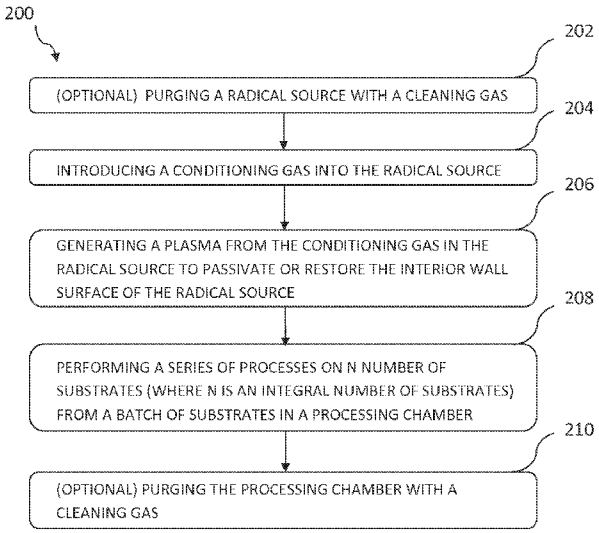


FIG. 2

(57) Abstract: Embodiments of the present disclosure generally relate to methods for conditioning an interior wall surface of a remote plasma generator. In one embodiment, a method for processing a substrate is provided. The method includes exposing an interior wall surface of a remote plasma source to a conditioning gas that is in excited state to passivate the interior wall surface of the remote plasma source, wherein the remote plasma source is coupled through a conduit to a processing chamber in which a substrate is disposed, and the conditioning gas comprises an oxygen-containing gas, a nitrogen-containing gas, or a combination thereof. The method has been observed to be able to improve dissociation/recombination rate and plasma coupling efficiency in the processing chamber, and therefore provides repeatable and stable plasma source performance from wafer to wafer.

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CONDITIONING REMOTE PLASMA SOURCE FOR ENHANCED PERFORMANCE HAVING REPEATABLE ETCH AND DEPOSITION RATES

BACKGROUND

Field

[0001] Embodiments of the present disclosure generally relate to methods for conditioning remote plasma source.

Description of the Related Art

[0002] Plasma-enhanced chemical vapor deposition (PECVD) process is a process where electro-magnetic energy is applied to at least one precursor gas or vapor to transform the precursor into a reactive plasma. Forming a plasma can lower the temperature required to form a film, increase the rate of formation, or both. Plasma may be generated inside the processing chamber, *i.e.*, in situ, or in a remote plasma generator that is remotely positioned from the processing chamber. Remote plasma generators offer several advantages. For example, the remote plasma generator provides a plasma capability to a deposition system that does not have an in situ plasma system. The use of the remote plasma generator also minimizes the plasma interaction with the substrate and chamber components, thereby preventing the interior of the processing chamber from undesirable by-products of the plasma formation process.

[0003] Remote plasma generators generally have a protective anodized aluminum coating to protect the aluminum interior walls from degradation. However, anodized aluminum coatings are usually porous and prone to surface reactions. Therefore, the lifetime of anodized aluminum coatings is limited due to the degradation of the anodized coating in the plasma cleaning environment. Failure of the protective anodized coating over an aluminum surface leads to excessive particulate generation within the downstream reactor chamber. In addition, the downstream reactor chamber also suffers unstable plasma performance due to change in surface condition of the protective anodized coating as the process continues. Therefore, the wafer deposition/etch rates, film uniformity and plasma coupling efficiency from wafer to wafer are degraded.

[0004] While a frequent chamber cleaning may be performed to stabilize the chamber conditions, the chamber cleaning chemistries such as NF_3 will degrade the anodized coating to degrade at much faster rate. In some cases where the remote plasma source uses an AlN plasma block or anodized plasma block, the surface condition inside the remote plasma source will change over time with deposition or clean chemistries. This change in surface condition of the plasma block does not provide repeatable plasma performance resulting in inconsistent wafer-to-wafer performance over time.

[0005] Therefore, there is a need for methods for conditioning the surface of the remote plasma generator to provide stable and repeatable plasma performance while maintaining the substrate throughput.

SUMMARY

[0006] Embodiments of the present disclosure generally relate to methods for conditioning an interior wall surface of a remote plasma generator. In one embodiment, a method for processing a substrate is provided. The method includes exposing an interior wall surface of a radical source to a conditioning gas that is in excited state to passivate the interior wall surface of the radical source, wherein the radical source is coupled through a radical conduit to a processing chamber in which a substrate is disposed, and the conditioning gas comprises an oxygen-containing gas, a nitrogen-containing gas, or a combination thereof.

[0007] In another embodiment, the method includes (a) exposing an interior wall surface of a radical source to a conditioning gas that is in excited state to passivate the interior wall surface of the radical source, wherein the radical source is coupled through a radical conduit to a processing chamber in which a substrate is disposed, and the conditioning gas comprises an oxygen-containing gas, a nitrogen-containing gas, or a combination thereof, (b) performing a series of processes on N number of substrates from a batch of substrates in the processing chamber using radicals from the radical source, where N is an integral number of substrates between 1 and 20, and (c) repeating (a) and (b) until the last substrate in the batch of the substrates is processed and removed from the processing chamber.

[0008] In yet another embodiment, the method includes exposing an interior wall surface of a radical source to a conditioning gas, wherein the conditioning gas comprises an oxygen-containing gas, a nitrogen-containing gas, or a combination thereof, generating a plasma from the conditioning gas in the radical source to passivate the interior wall surface of the radical source, and performing a series of processes on N number of substrates in the processing chamber using radicals from the radical source, where N is an integral number of substrates between 1 and 20.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] So that the manner in which the above recited features of the present disclosure can be understood in detail, a more particular description of the disclosure, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only exemplary embodiments and are therefore not to be considered limiting of its scope, may admit to other equally effective embodiments.

[0010] Figure 1 is a cross-sectional view of an apparatus for forming dielectric films according to embodiments of the present disclosure.

[0011] Figure 2 illustrates a method for conditioning a radical source of Figure 1 according to embodiments of the present disclosure.

[0012] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements and features of one embodiment may be beneficially incorporated in other embodiments without further recitation.

DETAILED DESCRIPTION

[0013] Figure 1 is a cross-sectional view of an apparatus 100 for forming dielectric films according to embodiments of the present disclosure. In one embodiment, the apparatus 100 includes a processing chamber 102 and a radical source 104 coupled to the processing chamber 102. The radical source 104 may be

any suitable source that is capable of generating radicals. The radical source 104 may be a remote plasma source, such as a radio frequency (RF) or very high radio frequency (VHRF) capacitively coupled plasma (CCP) source, an inductively coupled plasma (ICP) source, a microwave induced (MW) plasma source, an electron cyclotron resonance (ECR) chamber, or a high density plasma (HDP) chamber. Alternatively, the radical source 104 may be an ultraviolet (UV) source or the filament of a hot wire chemical vapor deposition (HW-CVD) chamber. The radical source 104 may include one or more gas inlets 106 and the radical source 104 may be coupled to the processing chamber 102 by a radical conduit 108. One or more process gases, which may be radical-forming gases, may enter the radical source 104 via the one or more gas inlets 106. The one or more process gases may comprise an oxygen-containing gas, a nitrogen-containing gas, a hydrogen containing gas, or any combination thereof. Radicals generated in the radical source 104 travel into the processing chamber 102 through the radical conduit 108 coupling to the processing chamber 102.

[0014] The radical source 104 may have an anodized coating applied to the aluminum interior chamber walls to protect the underlying aluminum interior chamber walls from corrosion or degradation. In various embodiments, the anodized protective coating is formed from aluminum oxide or aluminum nitride.

[0015] The radical conduit 108 is a part of a lid assembly 112, which also includes a radical cavity 110, a top plate 114, a lid rim 116, and a dual-zone showerhead 118. The radical conduit 108 may comprise a material that is substantially nonreactive to radicals. For example, radical conduit 108 may comprise AlN, SiO_2, Y_2O_3, MgO, anodized Al_2O_3, sapphire, ceramics containing one or more of Al_2O_3, sapphire, AlN, Y_2O_3, MgO, or plastics. A representative example of a suitable SiO_2 material is quartz. Alternatively or additionally, radical conduit 108 may have a coating on the surface that contacts the radicals in operation. The coating may also comprise AlN, SiO_2, Y_2O_3, MgO, anodized Al_2O_3, sapphire, ceramics containing one or more of Al_2O_3, sapphire, AlN, Y_2O_3, MgO, or plastics. If a coating is used, the thickness of the coating may be between about 1 μm and about 1 mm. The coating may be applied using a spray coating process. The

radical conduit 108 may be disposed within and supported by a radical conduit support member 120. The radical conduit support member 120 may be disposed on the top plate 114, which rests on the lid rim 116.

[0016] The radical cavity 110 is positioned below and coupled to the radical conduit 108, and the radicals generated in the radical source 104 travel to the radical cavity 110 through the radical conduit 108. The radical cavity 110 is defined by the top plate 114, the lid rim 116 and the dual-zone showerhead 118. Optionally, the radical cavity 110 may include a liner 122. The liner 122 may cover surfaces of the top plate 114 and the lid rim 116 that are within the radical cavity 110. The liner 122 may comprise a material that is substantially nonreactive to radicals. For example, the liner 122 may comprise AlN, SiO_2, Y_2O_3, MgO, anodized Al_2O_3, sapphire, ceramics containing one or more of Al_2O_3, sapphire, AlN, Y_2O_3, MgO, or plastics. Alternatively or in addition to, the surfaces of the radical cavity 110 that are in contact with radicals may be composed of or coated with a material that is substantially nonreactive to radicals. For example, the surfaces may be composed of or coated with AlN, SiO_2, Y_2O_3, MgO, anodized Al_2O_3, sapphire, ceramics containing one or more of Al_2O_3, sapphire, AlN, Y_2O_3, MgO, or plastics. If a coating is used, the thickness of the coating may be between about 1 μm and about 1 mm. By not consuming the generated radicals, the radical flux to a substrate disposed in the processing chamber 102 is increased.

[0017] An ion filter 123 may be disposed in the radical cavity 110 between the top plate 114 and the dual-zone showerhead 118. The ion filter 123 may be a perforated plate that is electrically grounded. If the radicals are generated within a plasma, the ions, electrons, and ultraviolet radiation generated in the plasma may be blocked by the ion filter 123 in order to direct only radicals to the dual-zone showerhead 118 and to prevent damage to the deposited film. Ion filter 123 can also control the number of radicals that pass through. Radicals then pass through a plurality of tubes 124 disposed in the dual-zone showerhead 118 to enter into a processing region 128. The dual-zone showerhead 118 further includes a plurality of openings 126 that are smaller in diameter than the plurality of tubes 124. The plurality of openings 126 are connected to an internal volume (not shown) that is not

in fluid communication with the plurality of tubes 124. One or more fluid sources 119 may be coupled to the dual-zone showerhead 118 for introducing a fluid mixture into a processing region 128 of the processing chamber 102. The fluid mixture may include precursor, porogen, and/or carrier fluids. The fluid mixture may be a mixture of gases and liquids.

[0018] The processing chamber 102 may include the lid assembly 112, a chamber body 130 and a support assembly 132. The support assembly 132 may be at least partially disposed within the chamber body 130. The chamber body 130 may include a slit valve 135 to provide access to the interior of the processing chamber 102. The chamber body 130 may include a liner 134 that covers the interior surfaces of the chamber body 130. The liner 134 may include one or more apertures 136 and a pumping channel 138 formed therein that is in fluid communication with a vacuum system 140. The apertures 136 provide a flow path for gases into the pumping channel 138, which provides an egress for the gases within the processing chamber 102.

[0019] The vacuum system 140 may include a vacuum port 142, a valve 144 and a vacuum pump 146. The vacuum pump 146 is in fluid communication with the pumping channel 138 via the vacuum port 142. The apertures 136 allow the pumping channel 138 to be in fluid communication with the processing region 128 within the chamber body 130. The processing region 128 is defined by a lower surface 148 of the dual-zone showerhead 118 and an upper surface 150 of the support assembly 132, and the processing region 128 is surrounded by the liner 134.

[0020] The support assembly 132 may include a support member 152 to support a substrate (not shown) for processing within the chamber body 130. The substrate may be any standard wafer size, such as, for example, 300 mm. Alternatively, the substrate may be larger than 300 mm, such as 450 mm or larger. The support member 152 may comprise aluminum nitride (AlN) or aluminum depending on operating temperature. The support member 152 may be configured to chuck the

substrate and the support member 152 may be an electrostatic chuck or a vacuum chuck.

[0021] The support member 152 may be coupled to a lift mechanism 154 through a shaft 156 which extends through a centrally-located opening 158 formed in a bottom surface of the chamber body 130. The lift mechanism 154 may be flexibly sealed to the chamber body 130 by bellows 160 that prevents vacuum leakage from around the shaft 156. The lift mechanism 154 allows the support member 152 to be moved vertically within the chamber body 130 between a process position and a lower, transfer position. The transfer position is slightly below the opening of the slit valve 135. During operation, the spacing between the substrate and the dual-zone showerhead 118 may be minimized in order to maximize radical flux at the substrate surface. For example, the spacing may be between about 100 mm and about 5,000 mm. The lift mechanism 154 may be capable of rotating the shaft 156, which in turn rotates the support member 152, causing the substrate disposed on the support member 152 to be rotated during operation.

[0022] One or more heating elements 162 and a cooling channel 164 may be embedded in the support member 152. The heating elements 162 and cooling channel 164 may be used to control the temperature of the substrate during operation. The heating elements 162 may be any suitable heating elements, such as one or more resistive heating elements. The heating elements 162 may be connected to one or more power sources (not shown). The heating elements 162 may be controlled individually to have independent heating and/or cooling control on multi-zone heating or cooling. With the ability to have independent control on multi-zone heating and cooling, the substrate temperature profile can be enhanced at any giving process conditions. A coolant may flow through the channel 164 to cool the substrate. The support member 152 may further include gas passages extending to the upper surface 150 for flowing a cooling gas to the backside of the substrate.

[0023] An RF source may be coupled to either the dual-zone showerhead 118 or the support member 152. The RF source may be low frequency, high frequency, or very high frequency. In one embodiment, the dual-zone showerhead 118 is coupled

to the RF source and the support member 152 is grounded, as shown in Figure 1. In another embodiment, the dual-zone showerhead 118 is grounded and the support member 152 is coupled to the RF source. In either embodiment, a capacitively coupled plasma may be formed in the processing region 128 between the dual-zone showerhead 118 and the support member 152 during operation. The capacitively coupled plasma formed in the processing region 128 is in addition to the plasma formed in the radical source when the radical source is a remote plasma source. The support member 152 may be biased with a DC source to increase ion bombardment.

[0024] Figure 2 illustrates a method 200 for conditioning the radical source 104 of Figure 1 according to embodiments of the present disclosure. It should be noted that the method 200 may be applicable to any remote plasma source that is positioned remotely from the processing chamber in which a substrate is disposed. The method 200 may be performed before, during, or after processing of each substrate (*e.g.,* deposition or etch process) in the processing chamber. In some embodiments, the method 200 may be performed periodically after a predetermined number of substrates, such as about 2 to about 15 substrates, have been processed. In such a case, the method 200 may be performed without the substrate being presented in the processing chamber. It should be noted that the sequence of steps illustrated in Figure 2 are not intended to be limiting as to the scope of the disclosure described herein, since one or more steps may be added, deleted and/or reordered without deviating from the basic scope of the disclosure.

[0025] At block 202, the radical source 104 is optionally purged with a cleaning gas. The cleaning gas may be introduced into the radical source 104 from a cleaning gas source through one or more gas inlets 106. The cleaning gas may be thermally activated and/or plasma-assisted under process conditions suitable to effectively remove any unwanted debits or by-products from the radical source 104. Exemplary cleaning gas may include, but is not limited to NF_3, NH_3, F_2, CF_4, C_2F_6, C_4F_8, SF_6, CHF_3, CF_6, H_2, CCl_4, C_2Cl_6, or any combination thereof. Optionally, the cleaning gas may further include an inert gas, such as argon or helium. In some embodiments, the cleaning gas may be introduced into the radical source 104 along

with a conditioning gas, as will be described below at block 204. In some embodiments, the above cleaning process may be performed in the processing chamber 102. The cleaning process may be performed for about 3 seconds to about 300 seconds, depending upon the number of substrates processed in the processing chamber between each cleaning.

[0026] At block 204, a conditioning gas is introduced into the radical source 104 from a conditioning gas source through one or more gas inlets 106. In various embodiments, the conditioning gas may include an oxygen-containing gas, a nitrogen-containing gas, or a combination thereof. Exemplary oxygen-containing gas may include, but is not limited to, one or more of the following: oxygen (O_2) gas, ozone (O_3) gas, nitrous oxide (N_2O), nitrogen monoxide (NO), carbon monoxide (CO), carbon dioxide (CO_2), water vapor (H_2O), or any combination thereof. Exemplary nitrogen-containing gas may include, but is not limited to, one or more of the following: ammonia (NH_3), nitrogen (N_2), hydrazine (N_2H_4), nitric oxide (NO), nitrous oxide (N_2O), or nitrogen dioxide (NO_2), or any combination thereof. The use of a conditioning gas containing oxygen-containing gas may be advantageous if the anodized protective coating of the radical source 104 is aluminum oxide. The use of a conditioning gas containing nitrogen-containing gas may be advantageous if the anodized protective coating of the radical source 104 is aluminum nitride. In some embodiments, a conditioning gas comprising a oxygen-containing gas may be used in cases where the anodized protective coating of the radical source 104 is aluminum nitride. In some embodiments, a conditioning gas comprising a nitrogen-containing gas may be used in cases where the anodized protective coating of the radical source 104 is aluminum oxide.

[0027] A chemically inert gas, such as helium gas, nitrogen gas, or argon gas, may be flowed into the processing chamber with the conditioning gas. If an inert gas is used, the inert gas may be introduced at an inert gas to conditioning gas ratio of about 1:1 to about 1:20, such as about 1:6 to about 1:15, for example about 1:10. In one embodiment, the conditioning gas may be introduced into the radical source 104 at a flow rate between about 2000 sccm and about 20000 sccm and at a chamber pressure of about 0.1 Torr to about 20 Torr.

[0028] At block 206, a plasma is generated from the conditioning gas in the radical source 104 to passivate or restore the interior wall surface of the radical source 104. In some embodiments, instead of striking the plasma within the radical source 104, a conditioning gas in an excited state may be flowed into the radical source 104 from a remote plasma source that is separate from the radical source. The term "excited state" used herein refers to a gas wherein at least some of the gas molecules are in vibrationally-excited, dissociated and/or ionized states. Alternatively, the passivation of the interior wall surface of the radical source 104 may be performed using a plasma-free process. That is, the conditioning gas is introduced into the radical source 104 and excited or dissociated at an elevated temperature suitable for thermal decomposition of the conditioning gas.

[0029] In case the radical source 104 is a capacitively coupled plasma (CCP) type source, the radical source 104 may be maintained at a pressure of about 0.1 Torr to about 20 Torr, for example about 1 Torr to about 10 Torr, and a temperature of about 250°C to about 400°C during the passivation. If the conditioning gas is dissociated using a RF power, the RF power density supplied to the radical source 104 may be between about 0.001 W/cm^2 to about 5 W/cm^2, such as from about 0.01 W/cm^2 to about 1 W/cm^2, for example about 0.04 W/cm^2 to about 0.07 W/cm^2.

[0030] The processing time for the passivation of the interior wall surface of the radical source 104 may vary depending upon the number of the substrates processed (*i.e.*, substrate process time) and/or the duration of the process (*e.g.,* deposition or etch process) performed on the substrate within the processing chamber 102 (*i.e.*, substrate process time) between each passivation process. In most cases, the passivation process time may be between about 2 seconds and about 30 seconds, such as about 3 seconds to about 25 seconds, for example about 10 seconds. In various embodiments, the passivation process time and the substrate process time may be at a ratio of about 1:5 to about 1:30, such as about 1:8 to about 1:20, for example about 1:12.

[0031] At block 208, once the interior wall surface of the radical source 104 has been passivated or restored, a series of processes are performed on N number of

substrates (where N is an integral number of substrates) from a batch of substrates in the downstream processing chamber, *e.g.*, the processing chamber 102 of Figure 1. In one embodiment, the N ranges between 1 and 20 substrates, such as between about 3 substrates and about 10 substrates, for example about 5 substrates. The process may be any deposition and/or etch process used to deposit or etch, for example, oxide or nitride materials, silicon-containing materials, or carbon-containing materials, either doped or undoped. The deposition and/or etch process may use radicals from the radical source. In one example, the deposition process is a flowable chemical vapor deposition (CVD) using silicon-containing precursor and $NH_3/O_2/N_2/H_2$ oxidizer chemistries to deposit dielectric materials. During deposition or etch process, an oxygen-containing gas and/or a nitrogen-containing gas may be flowed into the radical source 104 to stabilize the plasma.

[0032] At block 210, after the series of deposition/etch processes are performed, an interior wall surface of the processing chamber 102 may be optionally purged using a cleaning process. The cleaning process can be the same cleaning process described above with respect with block 202. In one example, the processing chamber 102 is cleaned using a cleaning gas comprising NF_3, ammonia, or a combination of thereof. During the cleaning of the processing chamber 102, an oxygen-containing gas, such as the oxygen-containing gas described above with respect to block 204, may be flowed into the radical source 104 for conditioning the interior wall surface of the radical source 104.

[0033] During cleaning, the cleaning gas may be introduced into the processing chamber 102 at a flow rate between about 2000 sccm and about 20000 sccm. The processing chamber 102 may be maintained at a pressure of about 0.1 Torr to about 20 Torr. A RF power, if used, may be supplied to the processing chamber 102 at a density of about 0.001 W/cm^2 to about 5 W/cm^2, such as from about 0.01 W/cm^2 to about 1 W/cm^2, for example about 0.04 W/cm^2 to about 0.07 W/cm^2, to activate the cleaning gas.

[0034] The processes described at blocks 202-210 may be repeated until the last substrate in the batch of the substrates is finished with the process and removed from the processing chamber 102.

[0035] Various processes are contemplated and may be added to the method 200. In some embodiments, a seasoning process may be optionally performed before the deposition or etch process *(i.e.,* before block 208) or after the processing chamber 102 has been cleaned *(i.e.,* after block 210) to deposit a seasoning layer on the walls of the cleaned processing chamber 102. In such a case, the passivation process as described at blocks 204 and 206 may be performed immediately before and/or after the seasoning process. The protective layer may vary depending upon the process to be performed in the processing chamber 102. For example, if a nitrogen-containing layer is to be deposited on the substrate, a seasoning layer of silicon nitride may be deposited onto the chamber surface of the processing chamber 102. The seasoning layer acts as a glue layer so that the subsequently deposited nitrogen-containing materials tend to adhere thereto better than to the interior chamber surface of the processing chamber 102. Therefore, residual nitrogen-containing materials are less likely to become dislodged during substrate processing. The seasoning process may be carried out with no substrate in the processing chamber 102. Alternatively, a sacrificial (dummy) substrate may be placed in the processing chamber 102 during the seasoning process.

[0036] In cases where the cleaning process is performed in the processing chamber 102 after the deposition/etch process, an optional conditioning process may be performed to remove undesirable fluorine (F) or nitrogen (N) containing contaminants from the cleaning process that are bonded to, or adsorbed on, the chamber surfaces of the processing chamber 102. In one embodiment, a hydrogen-containing plasma may be generated in the processing chamber 102 by flowing 1200 sccm of hydrogen into the processing chamber 102 for 30 seconds, creating a plasma using 300 Watts of power. The hydrogen plasma reacts with the fluorine present in the processing chamber 102 and forms a volatile HF containing vapor that is readily removable via the chamber exhaust. The processing chamber 102 may be maintained at the temperature to be used for subsequent deposition/etch process,

and a pressure of about 1-10 Torr. The electrode spacing between the showerhead 118 and the support assembly 132 may be about 800-1500 mils.

[0037] Benefits of the present disclosure provide methods for passivating or restoring an interior wall surface of a remote plasma generator by exposing the interior wall surface to a plasma formed from a conditioning gas comprising an oxygen-containing gas, a nitrogen-containing gas, or a combination thereof. The inventive process restores and stabilizes the surface condition of the interior wall surface of the remote plasma source. Therefore, the lifetime of the protective anodized aluminum coating is improved even in the plasma cleaning environment, which leads to minimized particulate generation within the downstream reactor chamber. The inventive process thus results in improved deposition rate, improved deposition uniformity and plasma coupling efficiency in the processing chamber during subsequent deposition. As a result, a repeatable and stable plasma source performance from wafer to wafer is obtained.

[0038] While a frequent chamber cleaning may be performed to stabilize the chamber conditions, the chamber cleaning chemistries such as NF_3 will degrade the anodized coating to degrade at much faster rate. In some cases where the remote plasma source uses an AlN plasma block or anodized plasma block, the surface condition inside the remote plasma source will change over time with deposition or clean chemistries. This change in surface condition of the plasma block does not provide repeatable plasma performance resulting in inconsistent wafer-to-wafer performance over time

[0039] While the foregoing is directed to embodiments of the present disclosure, other and further embodiments of the disclosure may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

What is claimed is:

1. A method for processing a substrate, comprising:

(a) exposing an interior wall surface of a remote plasma source to a conditioning gas that is in excited state to passivate the interior wall surface of the remote plasma source, wherein the remote plasma source is coupled through a conduit to a processing chamber in which a substrate is disposed, and the conditioning gas comprises an oxygen-containing gas, a nitrogen-containing gas, or a combination thereof;

(b) performing a series of processes on N number of substrates from a batch of substrates in the processing chamber using radicals from the remote plasma source, where N is an integral number of substrates between 1 and 20; and

(c) repeating (a) and (b) until the last substrate in the batch of the substrates is processed and removed from the processing chamber.

2. The method of claim 1, wherein the interior wall surface of the remote plasma source is formed from aluminum oxide or aluminum nitride and the conditioning gas is the oxygen-containing gas.

3. The method of claim 2, wherein the oxygen-containing gas comprises oxygen (O_2) gas, ozone (O_3) gas, nitrous oxide (N_2O), nitrogen monoxide (NO), carbon monoxide (CO), carbon dioxide (CO_2), water vapor (H_2O), or any combination thereof.

4. The method of claim 1, wherein the interior wall surface of the remote plasma source is formed from aluminum oxide or aluminum nitride and the conditioning gas is the nitrogen-containing gas.

5. The method of claim 4, wherein the nitrogen-containing gas comprises ammonia (NH_3), nitrogen (N_2), hydrazine (N_2H_4), nitric oxide (NO), nitrous oxide (N_2O), or nitrogen dioxide (NO_2), or any combination thereof.

6. The method of claim 1, wherein the conditioning gas further comprises a chemically inert gas, and the inert gas is at an inert gas to conditioning gas ratio of about 1:6 to about 1:15.

7. The method of claim 1, wherein the interior wall surface of the remote plasma source is exposed to the conditioning gas for about 3 seconds to about 25 seconds.

8. The method of claim 1, further comprising:

before (a), exposing an interior wall surface of the processing chamber to a cleaning gas, wherein the cleaning gas comprises NF_3, NH_3, F_2, CF_4, C_2F_6, C_4F_8, SF_6, CHF_3, CF_6, H_2, CCl_4, C_2Cl_6, or any combination thereof.

9. The method of claim 1, further comprising:

after (b), exposing an interior wall surface of the processing chamber to a cleaning gas, wherein the cleaning gas comprises NF_3, NH_3, F_2, CF_4, C_2F_6, C_4F_8, SF_6, CHF_3, CF_6, H_2, CCl_4, C_2Cl_6, or any combination thereof.

10. The method of claim 8 or 9, further comprising:

exposing the interior wall surface of the remote plasma source to an oxygen-containing gas during the cleaning of the processing chamber.

11. The method of claim 1, wherein the passivation time of the interior wall surface of the remote plasma source and the processing time for performing a series of processes on N number of substrates are at a ratio of about 1:5 to about 1:30.

12. The method of claim 1, wherein the conditioning gas further comprises a chemically inert gas, and the inert gas is at an inert gas to conditioning gas ratio of about 1:6 to about 1:15.

13. A method for processing a substrate, comprising:

exposing an interior wall surface of a remote plasma source to a conditioning gas, wherein the conditioning gas comprises an oxygen-containing gas, a nitrogen-containing gas, or a combination thereof;

generating a plasma from the conditioning gas in the remote plasma source to passivate the interior wall surface of the remote plasma source; and

performing a series of processes on N number of substrates in the processing chamber using radicals from the remote plasma source, where N is an integral number of substrates between 1 and 20.

14. The method of claim 13, wherein the conditioning gas further comprises a chemically inert gas, and the inert gas is at an inert gas to conditioning gas ratio of about 1:6 to about 1:15.

15. The method of claim 13, wherein the passivation time of the interior wall surface of the remote plasma source and the processing time for performing a series of processes on N number of substrates are at a ratio of about 1:5 to about 1:30.

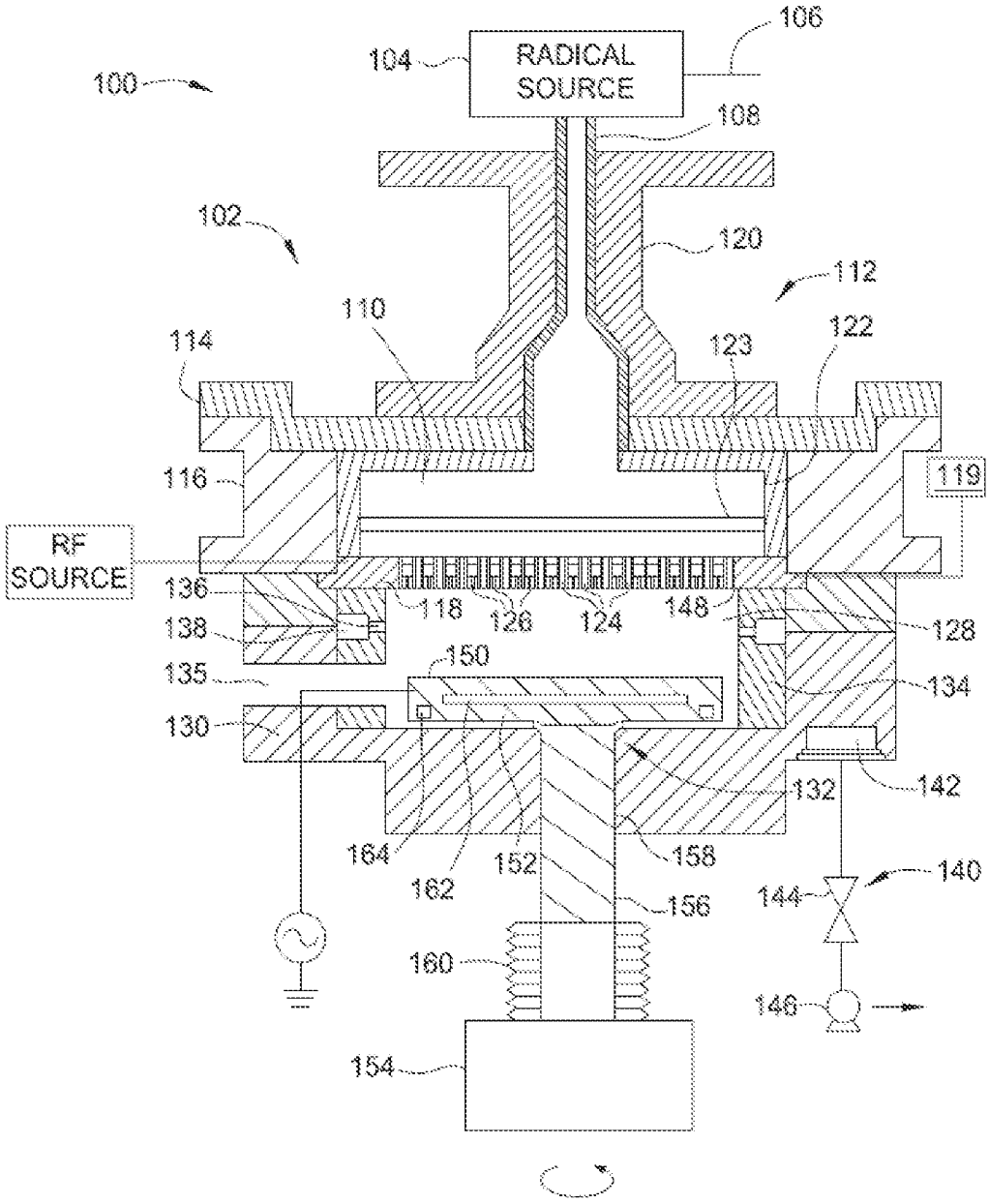

RADICAL SOURCE
RF SOURCE
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FIG. 1

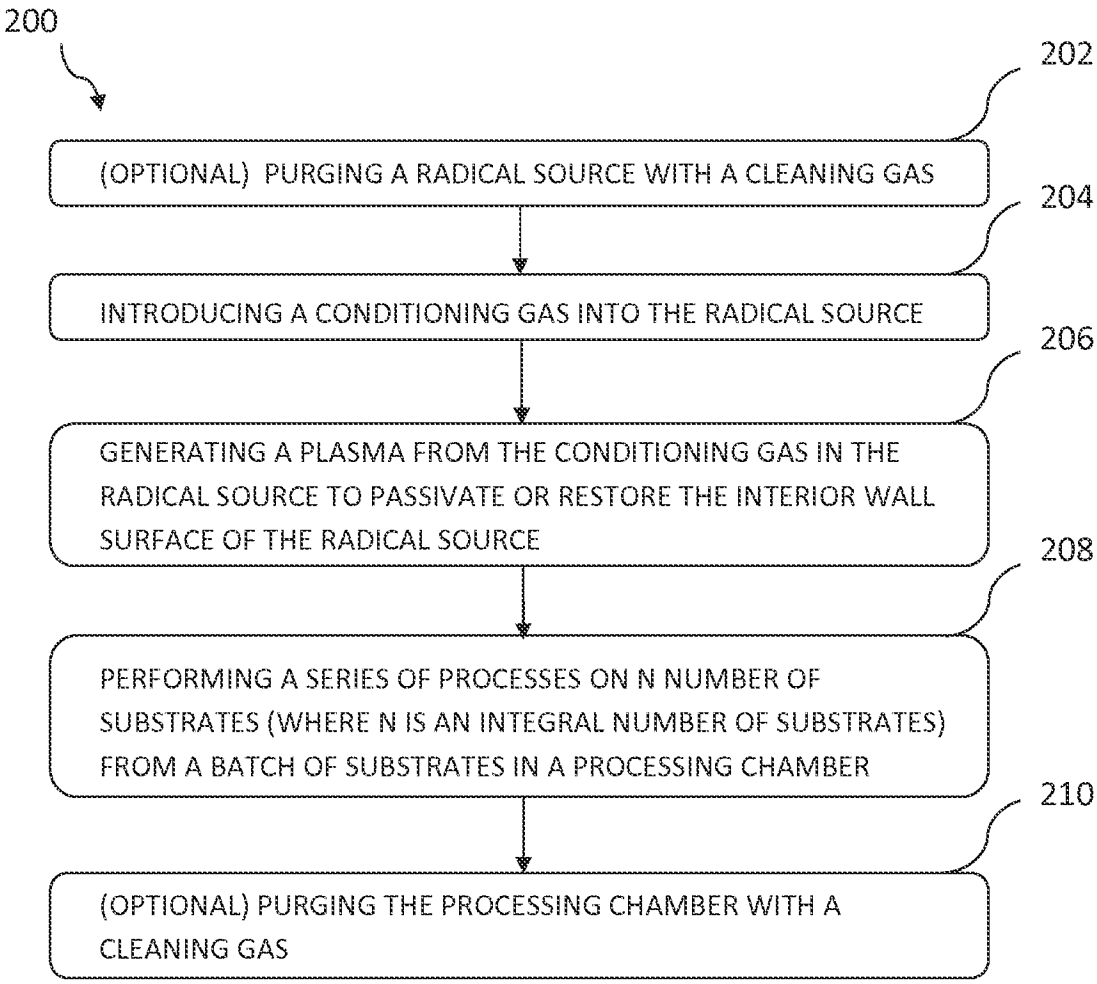

200
202
(OPTIONAL) PURGING A RADICAL SOURCE WITH A CLEANING GAS
204
INTRODUCING A CONDITIONING GAS INTO THE RADICAL SOURCE
206
GENERATING A PLASMA FROM THE CONDITIONING GAS IN THE RADICAL SOURCE TO PASSIVATE OR RESTORE THE INTERIOR WALL SURFACE OF THE RADICAL SOURCE
208
PERFORMING A SERIES OF PROCESSES ON N NUMBER OF SUBSTRATES (WHERE N IS AN INTEGRAL NUMBER OF SUBSTRATES) FROM A BATCH OF SUBSTRATES IN A PROCESSING CHAMBER
210
(OPTIONAL) PURGING THE PROCESSING CHAMBER WITH A CLEANING GAS

FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/028352

A. CLASSIFICATION OF SUBJECT MATTER

H01L 21/205(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01L 21/205; B08B 7/00; H05H 1/24; C23C 14/34; B08B 6/00; C23F 1/02; H01L 21/31; B08B 5/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & keywords: plasma, conditioning gas, passivation, interior, chamber

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2013-0084711 A1 (JINGMEI LIANG et al.) 04 April 2013 See abstract, paragraphs [0020]-[0027], claim 1 and figure 2.	1-15
A	US 2013-0048606 A1 (ZHIGANG MAO et al.) 28 February 2013 See abstract, paragraphs [0008]-[0009] and figure 2.	1-15
A	US 2007-0190266 A1 (XINYU FU) 16 August 2007 See abstract, paragraphs [0008]-[0010] and figure 5.	1-15
A	US 2002-0066532 A1 (HONG SHIH et al.) 06 June 2002 See abstract, paragraphs [0014]-[0015] and claim 1.	1-15
A	US 2011-0005922 A1 (CHIU-YING TAI et al.) 13 January 2011 See abstract, paragraphs [0009]-[0015] and figure 1.	1-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
31 July 2015 (31.07.2015)	**31 July 2015 (31.07.2015)**

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2015/028352

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