

PROCESSING CHAMBER PRECOAT WITH TRAPPING LAYER AND SEALING LAYER

BACKGROUND

[0001] Semiconductor manufacturing processes may include various steps of material deposition, patterning, and removal to fabricate integrated circuits. Example deposition processes include chemical vapor deposition (CVD) and atomic layer deposition (ALD). CVD involves exposing a substrate in a processing chamber to a flow of one or more processing chemicals under conditions configured to cause the one or more processing chemicals to form a film on the substrate. CVD may be performed on a substrate frontside or backside. Backside CVD may be performed, for example, to balance stresses on a substrate caused by frontside films and/or to protect the backside substrate from etching or various overlay errors caused by downstream process(es). ALD forms a film in a layer-by-layer process using a plurality of ALD cycles. Each ALD cycle comprises exposing a substrate in a processing chamber to a precursor. The precursor adsorbs to the substrate. Next, the processing chamber is purged. Then, the adsorbed precursor is chemically converted to a film layer.

[0002] In some semiconductor processing tools, a pretreatment process may be used prior to processing substrates in the processing tool. A pretreatment process may involve coating the interior surfaces of the processing chamber with one or more film layers to condition the processing chamber, including reducing the risk of the substrate being exposed to potential contaminants and/or unwanted particles.

SUMMARY

[0003] This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter. Furthermore, the claimed subject matter is not limited to implementations that solve any or all disadvantages noted in any part of this disclosure.

[0004] Examples are disclosed that relate to pretreating a processing chamber of a processing tool. One example provides a method for operating a processing tool. The method comprises, in a preprocessing phase, depositing an undercoat layer on

interior surfaces within a processing chamber of the processing tool. The method further comprises, in the preprocessing phase, depositing a precoat layer by performing one or more precoat cycles. Each precoat cycle comprises depositing a trapping layer on the interior surfaces within the processing chamber, the trapping layer comprising a first material. Each precoat cycle further comprises depositing a sealing layer over the trapping layer, the sealing layer comprising a second material different than the first material. The method further comprises, in a processing phase, performing a deposition process on a substrate to deposit a process film on the substrate after depositing the precoat layer.

[0005] In some such examples, the method further comprises cleaning the processing chamber to remove a previous undercoat layer and a previous precoat layer prior to performing the preprocessing phase.

[0006] Alternatively or additionally, in some such examples, the method further comprises, during the preprocessing phase, depositing a dummy layer of the process film on the interior surfaces within the processing chamber prior to performing the processing phase.

[0007] Alternatively or additionally, in some such examples, performing the one or more precoat cycles comprises performing a plurality of precoat cycles.

[0008] Alternatively or additionally, in some such examples, the method further comprises purging the processing chamber between each precoat cycle of the plurality of precoat cycles.

[0009] Alternatively or additionally, in some such examples, the plurality of precoat cycles comprises eight or more precoat cycles.

[0010] Alternatively or additionally, in some such examples, the trapping layer comprises a nitride layer and the sealing layer comprises an oxide layer.

[0011] Another example provides a processing tool. The processing tool comprises a processing chamber. The processing tool further comprises a substrate support disposed in the processing chamber. The processing tool further comprises flow control hardware configured to control gas flows from one or more gas sources into the processing chamber. The processing tool further comprises a plasma generator configured to form a plasma in the processing chamber. The processing tool further comprises a controller. The controller is further configured to, in a preprocessing phase, operate the flow control hardware and the plasma generator to deposit an undercoat layer onto interior surfaces within the processing chamber. The controller is further

configured to, in the preprocessing phase, operate the flow control hardware and the plasma generator to, for each precoat cycle of one or more precoat cycles, deposit a trapping layer comprising a first material and deposit a sealing layer comprising a second material that is different than the first material to form a precoat layer. The controller is further configured to, in a processing phase, operate the flow control hardware and the plasma generator to perform a deposition process on a substrate after depositing the precoat layer.

[0012] In some such examples, the controller is further configured to operate the flow control hardware and the plasma generator to perform a cleaning process on the processing chamber to remove a previous undercoat layer and a previous precoat layer prior to controlling the processing tool to perform the preprocessing phase.

[0013] Alternatively or additionally, in some such examples, the controller is further configured to operate the flow control hardware and the plasma generator to perform deposition of a dummy layer of a process film on the interior surfaces within the processing chamber prior to performing the deposition process.

[0014] Alternatively or additionally, in some such examples, the controller is further configured to control the flow control hardware and the plasma generator to perform a plurality of precoat cycles to form the precoat layer.

[0015] Alternatively or additionally, in some such examples, the controller is further configured to operate the flow control hardware and the plasma generator to perform a purging process between each precoat cycle of the plurality of precoat cycles.

[0016] Alternatively or additionally, in some such examples, the one or more gas sources comprise a silicon-containing source, an oxygen-containing source, and a nitrogen-containing source, and wherein the controller is configured to deposit the trapping layer by controlling the flow control hardware and the plasma generator to deposit a silicon nitride layer, and to deposit the sealing layer by controlling the flow control hardware and the plasma generator to deposit a silicon oxide layer.

[0017] Another example provides a substrate. The substrate comprises a film formed on a substrate. The substrate further comprises a surface concentration of particles of a selected metal on the film of less than 1×10^{10} atoms / cm².

[0018] In some such examples, the film is on a backside of the substrate.

[0019] In some such examples, the film is on a frontside of the substrate.

[0020] Alternatively or additionally, in some such examples, the film comprises a layer in a three-dimensional memory film stack.

[0021] Alternatively or additionally, in some such examples, the selected metal comprises aluminum.

[0022] Alternatively or additionally, in some such examples, the selected metal comprises one or more of sodium, magnesium, aluminum, potassium, calcium, titanium, vanadium, chromium, manganese, iron, cobalt, nickel, copper, zinc, yttrium, zirconium, molybdenum, tungsten, germanium, barium, strontium, or hafnium.

[0023] Alternatively or additionally, in some such examples, a total metal particulate concentration on the film is less than 1×10^{10} atoms / cm².

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] FIG. 1 schematically shows an example processing tool.

[0025] FIG. 2 shows a flow diagram depicting an example method of operating a processing tool.

[0026] FIGS. 3A-3H schematically show a magnified view of an interior surface of an example processing chamber at various stages during an example preprocessing phase and an example processing phase according to the method of FIG. 2.

[0027] FIG. 4 shows a graph of experimental results indicating surface concentrations of particles larger than 90 nm detected on substrates processed in processing chambers that underwent different example pretreatments.

[0028] FIG. 5 shows a graph of experimental results indicating surface concentrations of particles larger than 0.5 microns detected on substrates processed in processing chambers that underwent different example pretreatments.

[0029] FIG. 6 graphically shows surface concentrations of particles of aluminum detected on substrates processed in processing chambers that underwent different example pretreatments.

[0030] FIG. 7 graphically shows surface concentrations of particles of iron and manganese detected on substrates processed in processing chambers that underwent different example pretreatments.

[0031] FIG. 8 schematically shows an example three-dimensional memory film stack.

[0032] FIG. 9 shows a schematic diagram of an example computing system.

DETAILED DESCRIPTION

[0033] The term “aluminum-containing precursor” generally represents a chemical that can form a cobalt-aluminum nitride phase in a cobalt nitride layer when the cobalt nitride layer is exposed to the aluminum-containing precursor in a processing chamber. Example aluminum-containing precursors can include organoaluminum chemicals and aluminum halides. The term “aluminum halide” generally represents a chemical comprising aluminum bonded to halogen atoms. Examples include aluminum trichloride (AlCl_3), aluminum tribromide (AlBr_3), and aluminum triiodide (AlI_3). The term “organoaluminum chemical” generally represents a molecule comprising a carbon-aluminum bond. An organoaluminum chemical has a general structure $\text{R}_3\text{-Al}$, wherein at least one ligand R comprises a substituted or unsubstituted aliphatic group or substituted or unsubstituted aryl group. In some organoaluminum chemicals, one or two ligands R can independently comprise a hydride or a halide. Example organoaluminum chemicals include trialkylaluminum compounds, such as trimethylaluminum, triethylaluminum, and triisobutylaluminum. Other example organoaluminum chemicals include dimethylaluminum chloride, diethylaluminum chloride, and diisobutylaluminum hydride. Some gas phase trialkylaluminum compounds can comprise dimers. For example, diethylaluminum can dimerize to $\text{Al}_2(\text{C}_2\text{H}_5)_4(\mu\text{-C}_2\text{H}_5)_2$.

[0034] The term “atomic layer deposition” (ALD) generally represents a process in which a film is formed on a substrate in one or more individual layers by sequentially adsorbing a precursor conformally to the substrate and reacting the adsorbed precursor in self-limiting reactions to form a film layer. The terms “growth” and “deposition”, and variants thereof, also may be used to refer to film formation.

[0035] The term “carbon containing precursor” generally represents any compound that may be introduced into a processing chamber in a gas phase to form a carbon-containing film. Example carbon-containing precursors include low molecular-weight hydrocarbons. Examples of such hydrocarbons comprise alkanes having a general formula $\text{C}_n\text{H}_{2n+2}$ where $n = 1$ to 10 (such as, methane, ethane, etc.), alkenes having a general formula C_nH_{2n} where $n = 2$ to 10 (such as, ethylene, propylene, etc.), alkynes having a general formula $\text{C}_n\text{H}_{2n-2}$ where $n = 2$ to 10 (such as, acetylene, propyne, etc.) and other hydrocarbons (such as, cyclic hydrocarbons and nitrogen-containing compounds) that are gas-phase under processing conditions.

[0036] The term “chemical vapor deposition” (CVD) generally represents a process in which a solid phase film is formed on a substrate by continuously directing

a flow of one or more precursor gases over the substrate surface under conditions configured to cause the chemical conversion of the precursor gases to the solid phase film.

[0037] The term “cleaning process” generally represents a process for removing deposited materials from an interior surface of a processing chamber.

[0038] The term “deposition process” generally represents a process in which a layer of a material is grown, deposited, or formed on a substrate. Example deposition processes include CVD and ALD, and their variations.

[0039] The term “dummy process film layer” generally represents a layer of a process film deposited as part of a preprocessing phase.

[0040] The term “flow control hardware” generally represents components configured to place one or more processing chemical sources in fluid connection with a processing chamber. Flow control hardware may comprise one or more conduits, manifolds, mass flow controllers, and/or valves, for example.

[0041] The term “plasma generator” generally represents a device configured to generate a plasma to enhance and/or provide reactive species and/or energetic ions for substrate processing and/or processing chamber cleaning.

[0042] The term “precoat cycle” generally represents a process for depositing a trapping layer and a sealing layer on interior surfaces of a processing chamber to form a trapping layer/sealing layer pair. The precoat cycle is performed before performing substrate processing.

[0043] The term “precoat layer” generally represents a film deposited by performing one or more precoat cycles. A precoat layer comprises one or more trapping layers alternating with one or more sealing layers.

[0044] The term “preprocessing phase” generally represents processes performed in a processing chamber prior to substrate processing. A preprocessing phase may be used to form a precoat layer within a processing chamber.

[0045] The term “processing phase” generally represents processes performed by a processing tool to deposit a process film on a substrate.

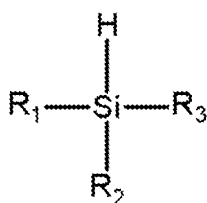
[0046] The term “processing chamber” generally represents an enclosure in which chemical and/or physical processes are performed on substrates. The pressure, temperature and atmospheric composition within a processing chamber are controllable to perform chemical and/or physical processes.

[0047] The term “process film” generally represents a film on a substrate in a processing phase of processing tool operation.

[0048] The term “purge” and variants thereof generally represent a process in which a gas is flowed through a processing chamber to remove unwanted species.

[0049] The term “sealing layer” generally represents a film deposited on interior surfaces of a processing chamber as part of a precoat layer. A sealing layer may be deposited on top of a trapping layer to make it more difficult for the particles trapped in the trapping layer to escape or be released from it. A sealing layer may be deposited on other layers, including the trapping layer.

[0050] The term “silicon-containing precursor” generally represents any compound that may be introduced into a processing chamber in a gas phase to form a silicon-containing film. Example silicon-containing films include silicon oxide (SiO_2), silicon nitride (Si_3N_4), silicon oxynitride (SiO_xN_y , $0 \leq x \leq 2$, $0 \leq y \leq 1.33$, hereinafter SiON), silicon carbide (SiC), silicon oxycarbide ($\text{SiC}_x\text{O}_{2(1-x)}$, $0 \leq x \leq 1$), silicon carbonitride ($x\text{Si}_3\text{N}_4 \cdot (1-x)\text{SiC}$), and silicon oxycarbonitride ($\text{SiO}_x\text{C}_y\text{N}_z$, $0 \leq x \leq 2$, $0 \leq y \leq 1$, $0 \leq z \leq 1.33$). Example silicon-containing precursors for forming silicon-containing films using CVD may comprise materials having the general structure:



Where R_1 , R_2 , and R_3 may be the same or different substituents. In various examples, R_1 , R_2 , and R_3 may include silanes, siloxy groups, amines, halides, hydrogen, or organic groups such as alkylamines, alkoxy, alkyl, alkenyl, alkynyl, and cyclic groups (such as aromatic groups).

[0051] Example silicon-containing precursors include silane and polysilanes ($\text{H}_3\text{Si}-(\text{SiH}_2)_n-\text{SiH}_3$), where $n \geq 0$, such as disilane, trisilane, tetrasilane, and trisilylamine. Silane and polysilanes are referred to herein as silanes or silane-based precursors. Silane-based precursors may include partially and substituted variants of silane and polysilanes.

[0052] In some examples, the silicon-containing precursor is an alkoxysilane. Alkoxysilanes that may be used include compounds having a general formula of $H_x-Si-(OR)_y$, where $x = 1-3$, $x+y = 4$, and each R is a substituted or unsubstituted aliphatic or aromatic group; and $H_x(RO)_y-Si-Si-(OR)_yH_x$, where each R is a substituted or unsubstituted aliphatic or aromatic group. Example alkoxysilanes include tetramethoxysilane (TMOS), diethoxymethylsilane (DEMS), diethoxysilane (DES), dimethoxymethylsilane, dimethoxysilane (DMOS), methyl-diethoxysilane (MDES), methyl-dimethoxysilane (MDMS), t-butoxydisilane, triethoxysilane (TES), and trimethoxysilane (TMS or TriMOS).

[0053] In some examples, the silicon-containing precursor is a siloxane. Siloxanes include materials having Si-O-Si linkages. Example siloxanes include octamethylcyclotetrasiloxane (OMCTS), octamethoxydodecasiloxane (OMODDS), and tetramethylcyclotetrasiloxane (TMCTS).

[0054] In some examples, the silicon-containing precursor is an aminosilane. Aminosilanes include materials having a general formula $H_x-Si-(NR)_y$, where $x = 1-3$, $x+y = 4$, and R is a substituted or unsubstituted alkyl, substituted or unsubstituted alkenyl, substituted or unsubstituted alkynyl, substituted or unsubstituted aromatic group, or hydride group. Example aminosilanes include bisdiethylaminosilane, diisopropylaminosilane, bis(t-butylamino) silane (BTBAS), di-sec-butylaminosilane, and tris(dimethylamino)silane (3DMAS).

[0055] In some examples, the silicon-containing precursor is a halogen-containing silane or halogen-containing polysilane. Halogen-containing silanes and halogen-containing polysilanes are examples of silane-based precursors. In some examples, a halogen-containing silane may comprise at least one hydrogen atom. Such a silane may have a general formula of SiX_aH_y where $y \geq 1$. Example halosilanes include dichlorosilane (H_2SiCl_2), hexachlorodisilane (Si_2Cl_6), and diiodosilane (H_2SiI_2).

[0056] More specific examples of silicon-containing precursors include tetraethylorthosilicate (TEOS), methylsilane, trimethylsilane (3MS), ethylsilane, butasilanes, pentasilanes, octasilanes, heptasilane, hexasilane, cyclobutasilane, cycloheptasilane, cyclohexasilane, cyclooctasilane, cyclopentasilane, 1,4-dioxo-2,3,5,6-tetrasilacyclohexane, triethoxysiloxane (TRIES), and tetraoxymethylcyclotetrasiloxane (TOMCTS).

[0057] The term “substrate” generally represents any object on which a film may be deposited. A semiconductor wafer is an example of a substrate.

[0058] The term “surface concentration” generally represents a number of particles on a substrate per unit area.

[0059] The term “trapping layer” generally represents a film deposited on interior surfaces (e.g., directly on the surfaces of chamber walls and/or components, or on the surface of one or more films of material(s) formed on the chamber walls and/or components) of a processing chamber as part of a precoat layer. A trapping layer comprises trapping sites to which mobile ions and other mobile species may bind. A trapping layer may be deposited on other layers, including an undercoat layer and a previously deposited sealing layer.

[0060] The term “undercoat layer” generally represents a film deposited on interior surfaces of a processing chamber before depositing a precoat layer. An undercoat layer may be used to provide for stronger adhesion than a metal processing chamber surface for a precoat layer.

[0061] As mentioned above, the fabrication of electronic devices involves many steps of material deposition, patterning, and removal to form integrated circuits. Example deposition processes include CVD and ALD. In such processes, mobile particles in the processing chamber, such as metal particles from metal surfaces within the processing chamber, by themselves and/or in combination with other chemicals provided inside the processing chamber, may contaminate substrates being processed. Metal particle contamination may, for example, lead to short circuiting and/or improper patterning on the substrate. This may cause reduced device yields compared to yields in the absence of such contaminants. Particulate contamination particularly may be an issue with smaller feature sizes, as the size of particles that may cause shorts decreases as feature size decreases.

[0062] To help reduce the concentration of mobile particles in a processing chamber, the processing chamber may be pretreated in a preprocessing phase of operation before being used to process substrates in a processing phase of operation. A pretreatment may comprise the deposition of one or more film layers over interior surfaces within the processing chamber prior to processing substrates in the processing chamber. Such film layers may be deposited, for example, after performing a cleaning process on the processing chamber. As an example, a pretreatment may involve first depositing a silicon oxide layer (an undercoat layer), followed by a silicon nitride layer

(a precoat layer) on interior surfaces of a processing chamber. The silicon oxide undercoat layer may provide for suitable and/or sufficient adhesion of the subsequently deposited silicon nitride precoat layer. The silicon nitride precoat layer may help to trap metal particles that may be present inside the processing chamber. Silicon nitride films may be relatively more porous than silicon oxide films. Silicon nitride films also may have higher surface energies than silicon oxide films. As such, a silicon nitride pretreatment film may attract and bind mobile particles at trapping sites on its surface and within its pores. This may help to reduce the risk of metal particulate contamination of substrates.

[0063] Pretreating a processing chamber before processing substrates also may provide other benefits. For example, pretreating the processing chamber by coating the interior surfaces of the processing chamber with one or more dielectric material layers may help to prevent arcing between an electrode used to form a plasma in the processing chamber and a metal (e.g., aluminum alloy) wall of the processing chamber. Such arcing may cause catastrophic damage to a processing tool. Pretreating the processing chamber also may help to match an impedance of the processing chamber to an on-substrate deposition impedance setting. This may help to avoid process drift during deposition.

[0064] However, a pretreatment comprising a silicon oxide undercoat layer and a silicon nitride precoat layer may not provide for suitably low metal particulate contamination levels on subsequently processed substrates to achieve a desired device yield in some processes. For example, some integrated circuit manufacturing processes require 1×10^{10} atoms / cm^2 or lower of metal contamination on the frontside of the substrate. However, the trapping sites of a silicon nitride precoat layer may be filled while still leaving an undesirable quantity of mobile metal particles in the processing chamber.

[0065] To help further reduce metal particulate contamination, a dummy process film layer may be deposited over the silicon nitride precoat layer. However, this still may not achieve a suitably low metal particulate contamination level for some integrated circuit fabrication processes.

[0066] Accordingly, examples are disclosed that relate to pretreating a processing chamber in a manner that helps achieve lower metal particulate contamination levels than the above-described pretreatment methods. Briefly, the disclosed examples perform a pretreatment process that includes forming a precoat

layer comprising alternating trapping layers and sealing layers. Each trapping layer (e.g., silicon nitride) can trap mobile particles, such as metal particles. Further, each sealing layer (e.g., silicon oxide) seals the trapped particles. One or more precoat layers may be formed. The use of a plurality of precoat layers, each with a trapping layer and a sealing layer, may lower particulate contamination on subsequently processed substrates compared to the use of a single precoat layer. Using the examples described herein, substrate metal particulate concentrations may be reduced compared to other methods of pretreatment. In some examples, a 50% reduction of on-substrate metal surface concentration may be achieved using a plurality of alternating trapping and sealing layers compared to the use of a single silicon oxide undercoat layer followed by a silicon nitride precoat layer of comparable total thickness. This may help to increase device yields on substrates processed in the processing chamber. By reducing chamber contamination, the disclosed examples also help maintaining the processing tool more efficiently and in cost-effective way (including, e.g., less maintenance frequency, faster cleaning process, etc.).

[0067] Prior to discussing these examples in detail, FIG 1. shows a schematic view of an example processing tool 100 that can implement pretreatment process according to disclosed examples. Processing tool 100 is described in the context of a CVD tool, including plasma-enhanced CVD (“PECVD”) tool. However, a pretreatment according to the disclosed examples may be used in other types of processing tools, such as ALD tools.

[0068] Processing tool 100 is configured to perform a deposition process on a substrate 102. Example substrates include semiconductor substrates, such as silicon wafers. Processing tool 100 comprises a processing station 104 at which a substrate 102 may be processed. Processing station 104 is positioned within a processing chamber 106. In some examples, two or more processing stations 104 may be in a same processing chamber 106. This is illustrated in FIG. 1 by additional processing station(s) 107. Each additional processing station(s) 107 is positioned within the processing chamber 106.

[0069] Processing tool 100 is configured to allow processing to be selectively performed on a substrate frontside or a substrate backside. As such, processing tool 100 comprises a showerhead pedestal 108 configured to distribute processing chemicals (for example, reactive precursors, and/or inert gases) toward a substrate backside.

[0070] Processing tool 100 further comprises a showerhead 110 positioned facing the showerhead pedestal 108. Showerhead 110 is configured to distribute processing chemicals (for example, inert gases and/or reactive precursors) toward a substrate frontside, depending upon a process being performed. In some examples, showerhead 110 is electrically coupled to a radio frequency (RF) power supply 112 with an RF matching network 115. RF power supply 112 may be controlled by a controller 120, described in more detail below. In other examples, RF power may be provided to showerhead pedestal 108 instead of showerhead 110. In this example, RF power supply 112, RF matching network 115, showerhead 110, and showerhead pedestal 108 comprise a plasma generator configured to form a capacitively coupled plasma between showerhead pedestal 108 and showerhead 110. In other examples, a plasma generator may be configured to form an inductively coupled plasma. In yet further examples, a plasma generator may be configured to form a plasma at a location remote from the processing station 104 and additional processing stations 107. In such examples, flow control hardware may be used to deliver reactive species generated in the remote plasma to processing chamber 106. In still further examples, both showerhead 110 and showerhead pedestal 108 may be connected to RF power. In some such examples, more than one RF power supply/matching network may be used.

[0071] Substrate 102 is positioned on a carrier ring 124 that may be mechanically moved to other process stations. In FIG. 1, substrate 102 is positioned for backside processing. As such, carrier ring 124 is positioned on support 126 that are configured to hold substrate 102 a selected distance above showerhead pedestal 108. In this configuration, precursors may be distributed toward a backside of substrate 102 using showerhead pedestal 108, while inert gases may be distributed toward a frontside of substrate 102 using showerhead 110 (e.g., to prevent precursors directed to the backside from reaching the frontside).

[0072] When the frontside of substrate 102 is being processed, substrate 102 is positioned on showerhead pedestal 108, and carrier ring 124 rests on a carrier ring support region 127 of the showerhead pedestal 108. An end effector (not shown) may be used to place the substrate 102 and carrier ring 124 on showerhead pedestal 108 for frontside processing, or on supports 126 for backside processing.

[0073] In some examples, at least a portion of processing station 104 may move relative to processing chamber 106. For example, processing tool 100 may comprise a motor-driven bellows (not shown) to move showerhead pedestal 108 (together with the

substrate 102) vertically. The movement of showerhead pedestal 108 may be facilitated by one or more flexible gas lines (not shown) that are coupled to gas flow path components leading to showerhead pedestal 108.

[0074] The processing tool 100 further comprises a purge gas source 132. Purge gas source 132 comprise one or more inert gases. Controller 120 controls the delivery of inert gas from purge gas source 132 to showerhead 110 through flow path 133. As a specific example, when deposition is targeted for the backside of substrate 102, an inert gas flow is directed over the frontside of substrate 102 with the showerhead 110. The inert gas flow may prevent precursors entering the space between the showerhead 110 and the substrate front side and/or push precursors away from the substrate frontside, protecting frontside from unwanted processing during backside processing.

[0075] In various examples, processing chemicals may be premixed before introduction into processing chamber 106 or introduced separately into processing chamber 106. Process gases exit processing chamber 106 through one or more outlets. For example, an exhaust system 117 is employed to draw process gases out and maintain a suitable pressure within the reactor.

[0076] FIG. 1 also shows various processing chemical sources. Nitrogen source 134 is configured to provide a nitrogen-containing precursor to showerhead pedestal 108 through flow path 135. Example nitrogen-containing precursors include ammonia, molecular nitrogen, and hydrazine. Oxidant source 136 is configured to provide an oxidant to showerhead pedestal 108 through flow path 137. Example oxidants include molecular oxygen, water, nitrous oxide, ozone, and hydrogen peroxide. Silicon-containing precursor source 138 is configured to provide a silicon-containing precursor to showerhead pedestal 108 through flow path 139. The silicon-containing precursor 138 may be liquid or gas. Example silicon-containing precursor source 138 include those listed above. Flow paths 133, 135, 137, and 139 each may comprise any suitable flow control hardware to allow the selective delivery of processing chemicals to processing chamber 106.

[0077] Additional processing station(s) 107 also receive purge gas through flow path 133. Additional processing station(s) 107 also may receive nitrogen-containing precursors through flow path 135. Additional processing station(s) 107 also receive oxidant sources through flow path 137. Additional processing station(s) 107 also receive silicon-containing precursor through flow path 139. Additional processing station(s) 107 further may receive power from RF power supply 112 through RF

matching network 115. Additional processing station(s) 107 also may be controlled by controller 120. Example hardware for controller 120 is discussed below with reference to FIG. 8. In some examples, different RF power supplies/matching networks and/or different processing chemical sources may be applied to different stations so that processing at each separate processing station may be controlled independently.

[0078] As described above, a processing tool may be configured to perform a pretreatment process to pretreat a processing chamber after the processing chamber is cleaned and before processing substrates. FIG. 2 shows a flow diagram illustrating an example method 200 of operating a processing tool that includes pretreating a processing chamber. Method 200 may be performed by processing tool 100, for example. FIGS. 3A-3H show a schematic view of an example processing chamber 300 at various stages of performing method 200. Processing chamber 300 is an example of processing chamber 106.

[0079] Referring again to FIG. 2, at 210, method 200 comprises performing a preprocessing phase 210 to pretreat a processing chamber prior to processing substrates in the processing chamber. The preprocessing phase 210 comprises, at 220, optionally depositing an undercoat layer on interior surfaces within the processing chamber of the processing tool. The undercoat layer may help to provide for adhesion of subsequent layers deposited in the preprocessing phase. The undercoat layer further may, in conjunction with other pretreatment layers, help to avoid arcing from an electrode used to form a plasma. The undercoat layer additionally may, in conjunction with other pretreatment layers, help to impedance match the processing chamber and a substrate being processed. This may help to avoid process drift.

[0080] FIG. 3A shows a magnified view 301 of interior chamber surface 302 of processing chamber 300 prior to the deposition of the undercoat layer. FIG. 3B shows a magnified view 301 of interior chamber surface 302 following deposition of undercoat layer 304. In the example of FIG. 3B, processing chemicals that are used to form the undercoat layer are introduced through a showerhead pedestal 303 of the processing chamber 300. In other examples, the processing chemicals for forming the undercoat layer alternatively or additionally may be introduced through a showerhead 305. Details of interior structures of the showerhead pedestal 303 and showerhead 305 are omitted for clarity.

[0081] Any suitable material may be used as the undercoat layer. Suitable materials include materials that help to adhere precoat layers. Suitable materials also

include dielectric materials that help to prevent electrical arcs during plasma processing. In some examples, the undercoat layer comprises silicon oxide. Silicon oxide may provide for suitably strong adhesion to a subsequent stack of layers formed in the pretreatment process. Silicon oxide also is compatible with processes used to deposit silicon-containing films, and thus does not introduce contaminants into the processing chamber. Various silicon-containing precursors may be used to deposit a silicon oxide layer. In the example of FIG. 3B, silane (SiH_4) is introduced as a silicon-containing precursor. Silane is widely available, relatively inexpensive, and can be converted into an oxide film. Other example silicon-containing precursors include those listed above. In some examples, an oxidant may be provided as a source of oxygen to form the silicon oxide layer. In the example of FIG. 3B, nitrous oxide (N_2O) and molecular oxygen (O_2) are introduced as oxidants. Other example oxidants include ozone, hydrogen peroxide, and water. In some examples, a silicon-containing precursor may include oxygen atoms for forming the oxide. TEOS is an example of a silicon-containing precursor with oxygen atoms that may contribute to silicon oxide formation. In further examples, the undercoat may be formed from a different material than silicon oxide, such as aluminum oxide.

[0082] In some examples, a plasma may be used to facilitate the formation of the oxide undercoat layer. In the example of FIG. 3A-3H, a radio frequency (RF) power supply 307 is used to generate the radiofrequency plasma. RF power supply 307 provides power to showerhead 305, and showerhead pedestal 303 is grounded. In other examples, RF power may be provided to showerhead pedestal 303, and showerhead 305 may be grounded. In further examples, a processing tool may utilize a remote plasma source (not shown). The plasma used to deposit the undercoat layer may have any suitable frequency and power. In some examples, the plasma is a radiofrequency plasma. Example frequencies for radiofrequency plasmas include frequencies of 400 kHz, 13.56 MHz, 27 MHz, 60 MHz, and 90 MHz. Example powers include powers of 50 to 6000 W. Alternatively or additionally, in some examples, thermal energy may be used to deposit the undercoat layer.

[0083] The interior surfaces of the processing chamber may comprise any suitable material or materials. For example, the interior surfaces of the processing chamber may comprise an aluminum alloy. Aluminum alloys may include metals such as sodium, magnesium, aluminum, potassium, calcium, titanium, vanadium, chromium, manganese, iron, cobalt, nickel, copper, zinc, yttrium, zirconium, molybdenum,

tungsten, germanium, barium, strontium, and hafnium in various examples. In some examples, the interior surfaces of a processing chamber also may include ceramics. For example, ceramic showerheads, ceramic pedestals, and other ceramic parts may be used in a processing chamber intended for use at temperatures above 400 degrees Celsius. In some examples, a ceramic showerhead, pedestal, showerhead pedestal, and/or other ceramic parts may be used for processes at temperatures of 600 degrees Celsius, or even higher. Example ceramic materials include silicon nitride, aluminum nitride, and aluminum oxide. Interior surfaces of a processing chamber can be coated (finished) with various materials, and different surfaces can be finished with different materials.

[0084] In some examples, a single undercoat deposition step may be performed in an undercoat formation process. In other examples, a plurality of undercoat deposition steps may be used to form an undercoat comprising multiple layers of undercoat material.

[0085] Continuing, at 230, the preprocessing phase 210 further comprises depositing a precoat layer by performing one or more precoat cycles 240. Each precoat cycle comprises, at 242, depositing a trapping layer on the interior surfaces with the processing chamber, the trapping layer comprising a first material. FIG. 3C shows a magnified view 301 of interior chamber surface 302 after deposition of trapping layer 306. Trapping layer 306 is deposited on top of undercoat layer 304. Each precoat cycle further comprises, at 244, depositing a sealing layer over the trapping layer, the sealing layer comprising a second material that is different from the first material. FIG. 3D shows a magnified view 301 of interior chamber surface 302 after deposition of a sealing layer 308. Depositing the trapping layer may help to trap mobile particles. Trapping mobile particles helps to reduce a surface concentration of particles of selected metals on a substrate processed in the processing chamber after performing the pretreatment process. The sealing layer helps to seal trapped particles in the trapping layer, and also may provide a growth surface for a next trapping layer.

[0086] In some examples, the trapping layer comprises a silicon nitride layer. Silicon nitride is compatible with processes used to deposit silicon-containing films, and thus does not introduce contaminants into the processing chamber. As mentioned above, silicon nitride may provide trapping sites to trap mobile particles within the processing chamber. Silicon nitride may be relatively porous compared to silicon oxide. Silicon nitride further may have vacancies within the pores and dangling bonds at the surface. The vacancies and dangling bonds may serve as trapping sites for metal

particles. Further, silicon nitride may have a relatively higher surface energy compared to films such as silicon oxide. The surface energy and vacancies of the silicon nitride helps to trap metal particles and retain them in the silicon nitride layer. In other examples, other suitable materials than silicon nitride may be used as a trapping layer. Examples include aluminum nitride and silicon carbonitride. Deposition parameters, such as processing chamber pressure, substrate temperature, RF frequency (or frequencies for multi-frequency RF), RF power (or powers for multi-frequency RF), processing chemical selection, and processing chemical flow rates, may be optimized to tune the properties of the trapping layer, such as the density of the vacancies, crystal/amorphous phase proportion, grain size, surface morphology, etc.

[0087] Various silicon-containing precursors may be used to deposit a silicon nitride trapping layer. In the depicted example, FIG. 3C, silane (SiH_4) is introduced into the processing chamber 300 as a silicon-containing precursor. Other example silicon-containing precursors include those listed above. A nitrogen-containing precursor also may be introduced into the processing chamber to form the silicon nitride layer. In the example of FIG. 3C, ammonia (NH_3) and molecular nitrogen (N_2) are introduced as nitrogen-containing precursors. In other examples, one or the other of these materials may be introduced as the nitrogen-containing precursor. Other example nitrogen-containing precursors include hydrazine. Alternatively or additionally, a silicon-containing precursor may include nitrogen atoms as a source for at least some of the nitrogen atoms in the silicon nitride. Aminosilanes are an example of a silicon-containing precursor with nitrogen atoms that may contribute to silicon nitride formation.

[0088] In some examples, a plasma may be used to facilitate the formation of the nitride trapping layer. The plasma may have any suitable frequency and power. In some examples, the plasma is a radiofrequency plasma. In the example of FIG. 3A-3H RF power supply 307 is used to generate the radiofrequency plasma. 400 kHz, 13.56 MHz, 27 MHz, 60 MHz, and 90 MHz. Example powers include powers of 50 to 6000 W. Alternatively or additionally, in some examples, thermal energy may be used to deposit the oxide undercoat layer.

[0089] Depositing the sealing layer may help to further make it more difficult for the particles trapped in the trapping layer to escape or be released from it. This may help to reduce a surface concentration of particles of selected metals on a substrate processed in the processing chamber after performing the pretreatment process.

[0090] In some examples, the sealing layer comprises a silicon oxide layer. Silicon oxide is compatible with processes used to deposit silicon-containing films, and does not introduce contaminants into the processing chamber. Silicon oxide may have a relatively low surface energy and fewer vacancies compared to silicon nitride. The surface energy and lack of vacancies of the silicon oxide may help to keep trapped mobile particles trapped in the silicon nitride trapping layer. In other examples, other suitable materials than silicon oxide may be used as a sealing layer. Examples include aluminum oxide, silicon oxycarbide, and silicon oxynitride. Example aluminum-containing precursors for depositing an aluminum-containing film, such as aluminum oxide, include those listed above. Example carbon-containing precursors for forming a carbon-containing film, such as silicon oxycarbide, include those listed above. Deposition parameters, such as processing chamber pressure, substrate temperature, RF frequency (or frequencies for multi-frequency RF), RF power (or powers for multi-frequency RF), processing chemical selection, and processing chemical flow rates, may be optimized to tune the properties of the sealing layer, such as the density of the vacancies, crystal/amorphous phase proportion, grain size, surface morphology, etc.

[0091] Various silicon-containing precursors and processing conditions may be used to deposit a silicon oxide sealing layer. Example deposition conditions include those given above for forming a silicon oxide undercoat layer. Example silicon-containing precursors for forming the silicon oxide sealing layer also are listed above.

[0092] In some examples, a single precoat cycle may be performed in a precoat layer formation process. In other examples, a plurality of precoat cycles may be used to form a precoat layer comprising multiple layers of trapping layer/sealing layer pairs. FIG. 3E shows a magnified view 301 of interior chamber surface 302 after deposition of second trapping layer 310. Second trapping layer 310 is deposited on top of sealing layer 308. Second trapping layer 310 may or may not have the same chemistry, properties, and/or thickness as those of first trapping layer 306. For example, second trapping layer 310 may comprise a different material. As a more specific example, one of first trapping layer 306 and second trapping layer 310 may be formed from one of silicon nitride, silicon oxynitride, silicon carbonitride, or silicon oxycarbonitride, and the other of first trapping layer 306 and the second trapping layer 310 is formed from another of these materials. As another more specific example, one of first trapping layer 306 and second trapping layer 310 may be formed from a tensile silicon nitride, while the other is formed from a compressive silicon nitride. As a further more specific

example, one of first trapping layer 306 and second trapping layer 310 may be formed from silicon nitride, while the other is formed from aluminum nitride.

[0093] FIG. 3F shows a magnified view 301 of interior chamber surface 302 after deposition of second sealing layer 312. Second sealing layer 312 is deposited on top of second trapping layer 310. Second sealing layer 312 may or may not have the same chemistry, properties, or thickness as those of first sealing layer 308. For example, second sealing layer 312 may comprise a different material. As a more specific example, one of first sealing layer 308 and second sealing layer 312 may be formed from one of silicon oxide, silicon oxynitride, silicon oxycarbide, or silicon oxycarbonitride, and the other of first sealing layer 308 and the second sealing layer 312 is formed from another of these materials. As another more specific example, one of first sealing layer 308 and second sealing layer 312 may be formed from silicon oxide, while the other is formed from aluminum oxide.

[0094] Each precoat cycle may contribute to the reduction of metal particulate contamination on a substrate by trapping and sealing mobile particles. In some examples, a single trapping layer may not have enough trapping sites for a quantity of particles in the processing chamber. However, each additional trapping layer provides additional trapping sites. Thus, the use of a greater number of trapping layers allows a greater number of particles to be trapped. As a result, performing a plurality of precoat cycles may reduce metal particulate contamination on substrates that are subsequently processed in the processing chamber compared to the use of a single precoat cycle.

[0095] In some examples, at 246 an optional purge is performed during the precoat cycle. Purging the processing chamber may help to remove mobile particles or ions from the processing chamber. This may reduce the number of mobile particle or ions in the processing chamber. Purging may be performed after depositing the trapping layer and/or after depositing the sealing layer of a precoat layer.

[0096] At 250, method 200 optionally comprises depositing a dummy process film layer onto the interior surfaces of a processing chamber. Depositing the dummy process film layer may help ensure the processing chamber impedance is matched to a substrate processing deposition setting. This may help reduce process drift during substrate processing. FIG. 3G shows an example dummy process film 314.

[0097] Method 200 further comprises, at 260, a processing phase. At 270, method 200 further comprises performing a deposition process on a substrate to deposit a process film on the substrate after depositing the precoat layer, and after depositing

the optional dummy process film layer. For example, substrate 102 may be processed in such a manner. FIG. 3H shows an example substrate 316 in a processing phase. Any suitable films may be deposited in the processing phase. Where the undercoat layer and sealing layer(s) are silicon oxide and the trapping layer(s) are silicon nitride, example films that may be deposited on substrates include silicon oxide films, silicon nitride films, silicon oxynitride films, silicon oxycarbide films, and silicon oxycarbonitride films.

[0098] FIG. 4 shows a graph of experimental results indicating surface concentrations of particles larger than 90 nm detected on substrates processed in processing chambers that underwent different example pretreatments. Particles of different sizes may have different impacts on integrated circuit features having different spacings. For example, more closely spaced conductive features can be more easily shorted by a metal particle of a selected size than more widely spaced conductive features. The substrates were processed by a nitride film deposition. CE 1 represents a substrate processed in a processing chamber pretreated by depositing a silicon oxide undercoat layer and a silicon nitride precoat layer onto interior surfaces of the processing chamber. CE 2 represents a substrate processed in a processing chamber pretreated by (a) depositing a silicon oxide undercoat layer, (b) depositing a silicon nitride precoat layer, (c) purging the processing chamber, and (d) depositing a dummy process film layer. CE 3 represents a substrate processed in a processing chamber pretreated by (a) depositing a silicon oxide undercoat layer, and (b) depositing a precoat layer comprising (b.1) four silicon nitride layers and (b.2) four silicon oxide layers, and purging between every two layers. Loop 8x represents a substrate processed in a processing chamber pretreated by (a) depositing an oxide undercoat layer, (b) performing eight precoat cycles according to step 240 of method 200 (including purging after depositing each sealing layer) to form a precoat layer comprising eight silicon nitride trapping layer/silicon oxide sealing layer pairs, and (c) depositing a dummy process film layer onto interior surfaces of the processing chamber. Loop 16x represents a substrate processed in a processing chamber pretreated by (a) depositing a silicon oxide undercoat layer, (b) performing sixteen precoat cycles according to step 240 of method 200 (including purging after depositing each sealing layer) to form a precoat layer comprising sixteen silicon nitride trapping layer/silicon oxide sealing layer pairs, and (c) depositing a dummy process film layer onto interior surfaces of the processing chamber. Loop 32x represents a substrate processed in a processing chamber pretreated

by (a) depositing a silicon oxide undercoat layer, (b) performing thirty-two precoat cycles according to step 240 of method 200 (including purging after depositing each sealing layer) to form a precoat layer comprising thirty-two silicon nitride trapping layer/silicon oxide sealing layer pairs, and (c) depositing a dummy process film layer onto interior surfaces of the processing chamber. A total thickness of the precoat layer is similar for each of the pretreatments. Thus, the thicknesses of the individual silicon nitride and silicon oxide layers for the Loop 8x precoat layer were greater than the thicknesses of the individual silicon nitride and silicon oxide layers for the Loop 16x and Loop 32x precoat layers. A total time taken to perform the preprocessing phase for each of these examples likewise was similar. For each of these experiments, the silicon oxide and silicon nitride film layers were deposited using a capacitively coupled RF plasma. Silane and oxygen/nitrous oxide were used for forming the silicon oxide layers. Silane and ammonia/nitrogen were used for forming the silicon nitride layers. Particle count measurements were performed using inductively coupled plasma mass spectrometry (ICPMS).

[0099] The data in FIG. 4, which has a linear y-axis scale, shows approximately a 50% reduction in the surface concentration of particles larger than 90 nm detected on a substrate processed in the processing chamber between CE 1 and Loop 8x. Further, as seen in FIG. 4, increasing the number of precoat cycles performed from 8 to 16 results in a further reduction in the surface concentration of particles larger than 90 nm. Thus, a number of trapping layer/sealing layer pairs in a precoat layer applied to a processing chamber may be varied to achieve a desired metal particulate contamination level on substrates processed in the processing chamber. Further, as shown by CE 3, depositing a plurality of trapping layers followed by a plurality of sealing layers offers less benefit than depositing a plurality of alternating trapping/sealing layers.

[00100] FIG. 5 graphically shows a bar graph illustrating surface concentrations of particles larger than 0.5 microns detected on substrates after performing the various preprocessing and processing methods described above for FIG. 4. The vertical scale of FIG. 5 is linear. As can be seen, FIG. 5 shows approximately a 50% reduction in the surface concentration of particles larger than 0.5 microns detected on a substrate processed in the processing chamber between CE 1 and Loop 8x. Further, as seen in FIG. 5, increasing the number of precoat cycles performed from 8 to 32 results in a further reduction in the surface concentration of particles larger than 0.5 microns detected on a substrate processed in the processing chamber after pretreatment. Again,

as shown by CE 3, depositing a plurality of trapping layers followed by a plurality of sealing layers offers less benefit than alternating trapping/sealing layers.

[00101] FIG. 6 graphically shows surface concentrations of particles of aluminum detected on substrates after performing different example methods of pretreating a processing chamber having aluminum alloy walls and components (e.g. showerhead and showerhead pedestal). Particles of materials such as aluminum fluoride may be formed in a processing chamber cleaning process (which may use fluorine-based plasma etches). Thus, aluminum contamination is a risk in processing chambers after performing chamber cleaning between substrate processing. In FIG. 6, CE 4 represents a substrate processed in a processing chamber with no pretreatment. CE 5 represents a substrate processed in a processing chamber pretreated by depositing a silicon oxide undercoat layer and a silicon nitride precoat layer. CE 2 represents a substrate processed in a processing chamber pretreated by (a) depositing a silicon oxide undercoat layer, (b) depositing a silicon nitride precoat layer, (c) purging the processing chamber, and (d) depositing a dummy process film layer. Loop 2x represents a substrate processed in a processing chamber pretreated by (a) depositing an oxide undercoat layer, (b) performing two precoat cycles according to step 240 of method 200 (including purging after depositing each sealing layer) to form a precoat layer comprising two silicon nitride trapping layer/silicon oxide sealing layer pairs, and (c) depositing a dummy process film layer onto interior surfaces of the processing chamber. Loop 4x represents a substrate processed in a processing chamber pretreated by (a) depositing a silicon oxide undercoat layer, (b) performing four precoat cycles according to step 240 of method 200 (including purging after depositing each sealing layer) to form a precoat layer comprising four silicon nitride trapping layer/silicon oxide sealing layer pairs, and (c) depositing a dummy process film layer onto interior surfaces of the processing chamber. Loop 8x represents a substrate processed in a processing chamber pretreated by (a) depositing an oxide undercoat layer, (b) performing eight precoat cycles according to step 240 of method 200 (including purging after depositing each sealing layer) to form a precoat layer comprising eight silicon nitride trapping layer/silicon oxide sealing layer pairs, and (c) depositing a dummy process film layer onto interior surfaces of the processing chamber. A total thickness of the precoat layer is similar for each of the pretreatments. The silicon oxide and silicon nitride layers were deposited using PECVD with the precursors described above with regard to FIG. 4.

[00102] FIG. 6, for example, shows that pretreatments CE 5 and CE 2 result in detectable amounts of aluminum particles on a substrate after processing the substrate in the processing chamber. In contrast, FIG. 6 shows that Loop 2x, Loop 4x, and Loop 8x each result in non-detectable amounts of aluminum particles on a substrate after processing the substrate in the processing chamber. Thus, the use of precoat layers comprising trapping layer/sealing layer pairs was more effective at reducing aluminum particulate contamination than the other pretreatment methods tested.

[00103] FIG. 7 graphically shows surface concentrations of particles of iron and manganese detected on substrates after performing different example methods of pretreating a processing chamber. Iron and manganese are elements used in some aluminum alloys. In FIG. 7, CE 4 represents a substrate processed in a processing chamber with no pretreatment. CE 5 represents a substrate processed in a processing chamber pretreated by depositing a silicon oxide undercoat layer and a silicon nitride precoat layer. CE 2 represents a substrate processed in a processing chamber pretreated by (a) depositing a silicon oxide undercoat layer, (b) depositing a silicon nitride precoat layer, (c) purging the processing chamber, and (d) depositing a dummy process film layer. Loop 2x represents a substrate processed in a processing chamber pretreated by (a) depositing an oxide undercoat layer, (b) performing two precoat cycles according to step 240 of method 200 (including purging after depositing each sealing layer) to form a precoat layer comprising two silicon nitride trapping layer/silicon oxide sealing layer pairs, and (c) depositing a dummy process film layer onto interior surfaces of the processing chamber. Loop 4x represents a substrate processed in a processing chamber pretreated by (a) depositing a silicon oxide undercoat layer, (b) performing four precoat cycles according to step 240 of method 200 (including purging after depositing each sealing layer) to form a precoat layer comprising four silicon nitride trapping layer/silicon oxide sealing layer pairs, and (c) depositing a dummy process film layer onto interior surfaces of the processing chamber. Loop 8x represents a substrate processed in a processing chamber pretreated by (a) depositing an oxide undercoat layer, (b) performing eight precoat cycles according to step 240 of method 200 (including purging after depositing each sealing layer) to form a precoat layer comprising eight silicon nitride trapping layer/silicon oxide sealing layer pairs, and (c) depositing a dummy process film layer onto interior surfaces of the processing chamber. A total thickness of the precoat layer is similar for each of the pretreatments. Deposition

conditions for the silicon oxide and silicon nitride layers are described above with regard to FIG. 4.

[00104] FIG. 7, for example, shows that pretreatments CE 5, and CE 2 result in detectable amounts of iron and manganese on a substrate after processing the substrate in the processing chamber. However, FIG. 7 shows that Loop 2x, Loop 4x, and Loop 8x result in non-detectable amounts of manganese on a substrate after processing the substrate in the processing chamber. FIG. 7 shows that Loop 8x results in non-detectable amounts of iron on a substrate after processing the substrate in the processing chamber. Further, FIG. 7 shows a reduction in detectable amounts of iron on a substrate when comparing CE 5, and CE 2, with Loop 2x and Loop 4x. Thus, the use of precoat layers comprising trapping layer/sealing layer pairs was more effective at reducing iron and manganese contamination than the other pretreatment methods tested.

[00105] In some examples, having a thicker trapping layer may provide some benefit by reducing iron and zinc contamination. However, this benefit is less when compared to adding additional trapping layer/sealing layer pairs.

[00106] Thus, pretreating a processing chamber according to the disclosed examples helps reduce the concentration of mobile particles in a processing chamber. This helps to avoid contamination of a substrate processed in the processing chamber. By avoiding contamination of a substrate processed in the processing chamber, the disclosed examples help to avoid problems such as short circuiting and/or improper patterning on the substrate. By reducing chamber contamination, the disclosed examples also help maintaining the processing tool more efficiently and in cost-effective way (including, e.g., less maintenance frequency, faster cleaning process, etc.). This may help increase device yield and provide cost savings. The disclosed examples may be used in a variety of different electronic device manufacturing processes.

[00107] FIG. 8 schematically shows one example of a substrate 800 comprising a stack of films 802 on a substrate frontside, and a backside film 804. The stack of films 802 may represent an intermediate structure formed during an integrated circuit fabrication process. As one example, the stack of films 802 may represent an intermediate structure formed during a three-dimensional integrated circuit fabrication process. Three-dimensional integrated circuits include multiple layers of active devices, as opposed to a single layer. The stack of films 802 comprises alternating layers of a first material 806 and layers of a second material 808. The layers of the first material

806 and the layers of the second material 808 comprise various different materials, depending upon a type of three-dimensional integrated circuit being fabricated. Example three-dimensional integrated circuits include three-dimensional NAND memory (where NAND represents a NOT AND logic gate architecture), three-dimensional NOR memory (where NOR represents a NOT OR logic gate architecture), and three-dimensional DRAM (dynamic random-access memory). Example material pairs that may be used for the layers of the first material 806 and the layers of the second material 808 include silicon nitride/silicon oxide, silicon/silicon oxide and silicon/silicon-germanium. The number of alternating layers is variable, as shown in FIG. 8 by the break and triple dot in the stack of films 802. The number of layers varies depending upon a number of device layers to be included in the three-dimensional integrated circuit. It will be understood that other stacks of films besides three-dimensional memory stacks may cause stress on a substrate, and that backside deposition may be used to balance such stresses in an integrated circuit manufacturing process.

[00108] Stack of films 802 may put compressive or tensile stress on the substrate 800. This may potentially lead to deformation of substrate 800. Deformation of the substrate may lead to defects in the three-dimensional integrated circuits, or even substrate breakage. As such, substrate 800 also comprises a backside film 804 to balance the stresses from the stack of films 802 formed on the substrate frontside. This may help to prevent substrate deformation and/or breakage. Backside film 804 may comprise any suitable material. In some examples, backside film 804 is a tensile or compressive silicon nitride layer. In other examples, backside film 804 may be a silicon oxide layer. By pretreating a processing chamber used to deposit any of the layers of the stack of films 802 and/or the backside film 804 using the disclosed examples, particulate concentrations of a selected metal may be maintained at or below 1×10^{10} atoms / cm^2 on the layers of the first material 806, the layers of the second material 808, and/or the backside film 804. In some examples, a total metal particulate concentration may be maintained at or below 1×10^{10} atoms / cm^2 . While FIG. 8 shows a substrate comprising layers formed in a three-dimensional integrated circuit fabrication process, the disclosed examples may be used for pretreating processing chambers used to processing substrates in any other suitable application.

[00109] FIG. 9 schematically shows a non-limiting example of a computing system 900 that may enact one or more of the methods and processes described above.

Computing system 900 is shown in simplified form. Computing system 900 may take the form of one or more personal computers, workstations, computers integrated with substrate processing tools, and/or network accessible server computers.

[00110] Computing system 900 includes a logic subsystem 902 and a storage subsystem 904. Computing system 900 may optionally include a display subsystem 906, input subsystem 908, communication subsystem 910, and/or other components not shown in FIG. 9. Controller 120 is an example of computing system 900.

[00111] Logic subsystem 902 includes one or more physical devices configured to execute instructions. For example, the logic subsystem may be configured to execute instructions that are part of one or more applications, services, programs, routines, libraries, objects, components, data structures, or other logical constructs. Such instructions may be implemented to perform a task, implement a data type, transform the state of one or more components, achieve a technical effect, or otherwise arrive at a desired result.

[00112] The logic subsystem may include one or more processors configured to execute software instructions. Additionally or alternatively, the logic subsystem may include one or more hardware or firmware logic subsystems configured to execute hardware or firmware instructions. Processors of the logic subsystem may be single-core or multi-core, and the instructions executed thereon may be configured for sequential, parallel, and/or distributed processing. Individual components of the logic subsystem optionally may be distributed among two or more separate devices, which may be remotely located and/or configured for coordinated processing. Aspects of the logic subsystem may be virtualized and executed by remotely accessible, networked computing devices configured in a cloud-computing configuration.

[00113] Storage subsystem 904 includes one or more physical devices configured to hold instructions 912 executable by the logic subsystem to implement the methods and processes described herein. When such methods and processes are implemented, the state of storage subsystem 904 may be transformed—e.g., to hold different data.

[00114] Storage subsystem 904 may include removable and/or built-in devices. Storage subsystem 904 may include optical memory (e.g., CD, DVD, HD-DVD, Blu-Ray Disc, etc.), semiconductor memory (e.g., RAM, EPROM, EEPROM, etc.), and/or magnetic memory (e.g., hard-disk drive, floppy-disk drive, tape drive, MRAM, etc.), among others. Storage subsystem 904 may include volatile, nonvolatile, dynamic,

static, read/write, read-only, random-access, sequential-access, location-addressable, file-addressable, and/or content-addressable devices.

[00115] It will be appreciated that storage subsystem 904 includes one or more physical devices. However, aspects of the instructions described herein alternatively may be propagated by a communication medium (e.g., an electromagnetic signal, an optical signal, etc.) that is not held by a physical device for a finite duration.

[00116] Aspects of logic subsystem 902 and storage subsystem 904 may be integrated together into one or more hardware-logic components. Such hardware-logic components may include field-programmable gate arrays (FPGAs), program- and application-specific integrated circuits (ASIC / ASICs), program- and application-specific standard products (PSSP / ASSPs), system-on-a-chip (SOC), and complex programmable logic devices (CPLDs), for example.

[00117] When included, display subsystem 906 may be used to present a visual representation of data held by storage subsystem 904. This visual representation may take the form of a graphical user interface (GUI). As the herein described methods and processes change the data held by the storage subsystem, and thus transform the state of the storage subsystem, the state of display subsystem 906 may likewise be transformed to visually represent changes in the underlying data. Display subsystem 906 may include one or more display devices utilizing virtually any type of technology. Such display devices may be combined with logic subsystem 902 and/or storage subsystem 904 in a shared enclosure, or such display devices may be peripheral display devices.

[00118] When included, input subsystem 908 may comprise or interface with one or more user-input devices such as a keyboard, mouse, or touch screen. In some examples, the input subsystem may comprise or interface with selected natural user input (NUI) componentry. Such componentry may be integrated or peripheral, and the transduction and/or processing of input actions may be handled on- or off-board. Example NUI componentry may include a microphone for speech and/or voice recognition, and an infrared, color, stereoscopic, and/or depth camera for storage subsystem vision and/or gesture recognition.

[00119] When included, communication subsystem 910 may be configured to communicatively couple computing system 900 with one or more other computing devices. Communication subsystem 910 may include wired and/or wireless communication devices compatible with one or more different communication

protocols. As non-limiting examples, the communication subsystem may be configured for communication using a wireless telephone network, or a wired or wireless local- or wide-area network. In some examples, the communication subsystem may allow computing system 900 to send and/or receive messages to and/or from other devices using a network such as the Internet.

[00120] It will be understood that the configurations and/or approaches described herein are exemplary in nature, and that these specific examples or examples are not to be considered in a limiting sense, because numerous variations are possible. The specific routines or methods described herein may represent one or more of any number of processing strategies. As such, various acts illustrated and/or described may be performed in the sequence illustrated and/or described, in other sequences, in parallel, or omitted. Likewise, the order of the above-described processes may be changed.

[00121] The subject matter of the present disclosure includes all novel and non-obvious combinations and sub-combinations of the various processes, systems and configurations, and other features, functions, acts, and/or properties disclosed herein, as well as any and all equivalents thereof.

CLAIMS:

1. A method for operating a processing tool, the method comprising:
in a preprocessing phase,
depositing an undercoat layer on interior surfaces within a processing chamber of the processing tool, and
depositing a precoat layer by performing one or more precoat cycles, each precoat cycle comprising
depositing a trapping layer on the interior surfaces within the processing chamber, the trapping layer comprising a first material, and
depositing a sealing layer over the trapping layer, the sealing layer comprising a second material that is different than the first material; and
in a processing phase, performing a deposition process on a substrate to deposit a process film on the substrate after depositing the precoat layer.
2. The method of claim 1, further comprising cleaning the processing chamber to remove a previous undercoat layer and a previous precoat layer prior to performing the preprocessing phase.
3. The method of claim 1, further comprising, during the preprocessing phase, depositing a dummy layer of the process film on the interior surfaces within the processing chamber prior to performing the deposition process.
4. The method of claim 1, wherein performing the one or more precoat cycles comprises performing a plurality of precoat cycles.
5. The method of claim 4, further comprising purging the processing chamber between each precoat cycle of the plurality of precoat cycles.
6. The method of claim 4, wherein the plurality of precoat cycles comprises eight or more precoat cycles.
7. The method of claim 1, wherein the trapping layer comprises a nitride layer and the sealing layer comprises an oxide layer.

8. A processing tool, comprising:
a processing chamber;
a substrate support disposed in the processing chamber;
flow control hardware configured to control gas flows from one or more gas sources into the processing chamber;
a plasma generator configured to form a plasma in the processing chamber; and
a controller configured to
 in a preprocessing phase,
 operate the flow control hardware and the plasma generator to deposit an undercoat layer onto interior surfaces within the processing chamber, and
 operate the flow control hardware and the plasma generator to, for each precoat cycle of one or more precoat cycles,
 deposit a trapping layer comprising a first material, and
 deposit a sealing layer comprising a second material that is different than the first,
 to thereby form a precoat layer; and
 in a processing phase, operate the flow control hardware and the plasma generator to perform a deposition process on a substrate after depositing the precoat layer.
9. The processing tool of claim 8, wherein the controller is further configured to operate the flow control hardware and the plasma generator to perform a cleaning process on the processing chamber to remove a previous undercoat layer and a previous precoat layer.
10. The processing tool of claim 8, wherein the controller is further configured to operate the flow control hardware and the plasma generator to perform deposition of a dummy layer of a process film on the interior surfaces within the processing chamber prior to performing the deposition process.

11. The processing tool of claim 8, wherein the controller is further configured to control the flow control hardware and the plasma generator to perform a plurality of precoat cycles to form the precoat layer.
12. The processing tool of claim 11, wherein the controller is further configured to operate the flow control hardware and the plasma generator to perform a purging process on the processing chamber between each precoat cycle of the plurality of precoat cycles.
13. The processing tool of claim 8, wherein the one or more gas sources comprise a silicon-containing source, an oxygen-containing source, and a nitrogen-containing source, and wherein the controller is configured to deposit the trapping layer by controlling the flow control hardware and the plasma generator to deposit a silicon nitride layer, and wherein the controller is configured to deposit the sealing layer by controlling the flow control hardware and the plasma generator to deposit a silicon oxide layer.
14. A substrate, comprising:
 - a film formed on the substrate; and
 - a concentration of particles of a selected metal on the film of less than 1×10^{10} atoms / cm^2 .
15. The substrate of claim 14, wherein the film is on a backside of the substrate.
16. The substrate of claim 14, wherein the film is on a frontside of the substrate.
17. The substrate of claim 14, wherein the film comprises a layer in a three-dimensional memory film stack.
18. The substrate of claim 14, wherein the selected metal comprises aluminum.
19. The substrate of claim 14, wherein the selected metal comprises one or more of sodium, magnesium, aluminum, potassium, calcium, titanium, vanadium, chromium,

manganese, iron, cobalt, nickel, copper, zinc, yttrium, zirconium, molybdenum, tungsten, germanium, barium, strontium, or hafnium.

20. The substrate of claim 19, wherein a total metal particulate concentration on the film is less than 1×10^{10} atoms / cm².