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

[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 at 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

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. 9. 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

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 within 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 of 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. 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 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.

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 (c) purging between every two layers. Loop 8x represents a substrate processed in a processing chamber pretreated by (a) depositing a silicon 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

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 a silicon 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 a silicon 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 a silicon 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 a silicon 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

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 1, wherein the trapping layer comprises a nitride layer and the sealing layer comprises an oxide layer.

7. 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.

8. The processing tool of claim 7, 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.

9. The processing tool of claim 7, 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.

10. The processing tool of claim 7, 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.

11. The processing tool of claim 10, 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.

12. The processing tool of claim 7, 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.

13. 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.

14. The substrate of claim 13, 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.

15. The substrate of claim 14, wherein a total metal particulate concentration on the film is less than 1×10^{10} atoms / cm^2.