

ELECTROSTATIC CHUCK WITH POLARITY SWAPPING AND/OR POLARITY
BALANCING FOR WAFER BOW CONTROL AND NONUNIFORMITY IMPROVEMENT

CROSS-REFERENCE TO RELATED APPLICATIONS

5 [0001] This application claims the benefit of U.S. Provisional Application No.
63/627,499, filed on January 31, 2024. The entire disclosure of the application referenced
above is incorporated herein by reference.

FIELD

10 [0002] The present disclosure relates to substrate processing systems, and more
particularly to an electrostatic chuck (ESC) with polarity swapping and/or polarity
balancing during a substrate treatment.

BACKGROUND

15 [0003] The background description provided here is for the purpose of generally
presenting the context of the disclosure. Work of the presently named inventors, to the
extent it is described in this background section, as well as aspects of the description that
may not otherwise qualify as prior art at the time of filing, are neither expressly nor
impliedly admitted as prior art against the present disclosure.

20 [0004] Substrate processing systems may be used to treat substrates such as
semiconductor wafers. The treatments may include deposition, etching, cleaning, and/or
other treatments. During processing, a substrate is arranged on an electrostatic chuck
(ESC) in a processing chamber of the substrate processing system. Process gas
mixtures are introduced into the processing chamber using a gas delivery device. In some
processes, radio frequency (RF) plasma may be used to initiate chemical reactions.

25 [0005] During processing, the substrate is clamped to a ceramic top plate of the ESC.
To clamp the substrate, direct current (DC) voltages having the same magnitude and
opposite polarities are output to a pair of electrostatic electrodes embedded in the
ceramic top plate of the ESC. For example, during high bow and long deposition
processes, electrostatic clamping is used to maintain constant bow control and to prevent
backside discharge, backside deposition, and/or arcing. For example, 3D NAND
fabrication may involve high bow substrates and long deposition processes for depositing

thick layers. During these and other processes, it is important to limit substrate nonuniformity.

SUMMARY

[0006] A substrate processing system includes an electrostatic chuck (ESC) including a baseplate, a ceramic top plate, and a bonding layer arranged between the baseplate and the ceramic top plate. The ceramic top plate includes a first electrostatic electrode and a second electrostatic electrode embedded therein. A controller is configured to during one of N portions of a treatment of a substrate, clamp a substrate by supplying a first polarity to the first electrostatic electrode of the ESC and a second polarity to the second electrostatic electrode of the ESC, where N is an integer greater than one. During another one of the N portions of the treatment of the substrate, the controller is configured to clamp the substrate by supplying the second polarity to the first electrostatic electrode of the ESC and the first polarity to the second electrostatic electrode of the ESC.

[0007] In some examples, the treatment comprises deposition. The first electrostatic electrode and the second electrostatic electrode have a semicircular outer shape. A plasma generator is configured to generate plasma. The controller is configured to strike plasma during the one of the N portions of the treatment, extinguish the plasma between the one of the N portions and the another one of N portions of the treatment, and strike the plasma again during the another one of N portions of the treatment.

[0008] In other features, the controller is configured to de-clamp the substrate after extinguishing the plasma. The controller is configured to clamp the substrate before striking the plasma during the another one of N portions of the treatment.

[0009] A substrate processing tool includes S processing chambers including S ESCs, where S an integer greater than one. Each of the S ESCs includes a baseplate, a ceramic top plate, and a bonding layer arranged between the baseplate and the ceramic top plate. The ceramic top plates of the S ESCs include first electrostatic electrodes and second electrostatic electrodes. A controller is configured to, during one of N portions of S treatments of S substrates in the S processing chambers, clamp the S substrates in the S processing chambers, respectively, by supplying a first polarity to the first electrostatic electrodes of the S ESCs and a second polarity to the second electrostatic electrodes of the S ESCs, where N is an integer greater than one. During another one of the N portions of the S treatments of the S substrates, the controller is configured to clamp the S

substrates in the S processing chambers, respectively, by supplying the second polarity to the first electrostatic electrodes of the S ESCs and the first polarity to the second electrostatic electrodes of the S ESCs.

5 [0010] In other features, the S treatments comprise deposition. S plasma generators are configured to generate plasma in the S processing chambers. The controller is configured to strike plasma using the S plasma generators during the one of the N portions of the S treatments in the S processing chambers, extinguish the plasma in the S processing chambers between the one of the N portions and the another one of N portions, and strike the plasma in the S processing chambers during the another one of N portions of the S treatments.

15 [0011] In other features, the controller is configured to de-clamp the S substrates after extinguishing the plasma. The controller is configured to clamp the S substrates before striking the plasma during the another one of N portions of the S treatments. The first electrostatic electrodes and the second electrostatic electrodes in each of the S processing chambers are energized in a balanced configuration.

[0012] In other features, S is equal to four, the S processing chambers are arranged in 2 by 2 array, and the first electrostatic electrodes and the second electrostatic electrodes in each of the S processing chambers are energized in a balanced configuration.

20 [0013] In other features, S is equal to four, the S processing chambers are arranged in 2 by 2 array, and the first electrostatic electrodes and the second electrostatic electrodes in each of the S processing chambers are energized with facing electrodes in adjacent ones of the S processing chambers having opposite polarities.

25 [0014] In other features, S is equal to four, the S processing chambers are arranged in 2 by 2 array, and the first electrostatic electrodes and the second electrostatic electrodes in adjacent ones of the S processing chambers are rotated 90° relative to one another.

[0015] A method for clamping a substrate in a substrate processing system includes providing an electrostatic chuck (ESC) including a baseplate, a top plate, and a bonding layer arranged between the baseplate and the top plate, wherein the top plate includes a first electrostatic electrode and a second electrostatic electrode embedded therein.

30 During one of N portions of a treatment of a substrate, the method includes clamping a substrate by supplying a first polarity to the first electrostatic electrode of the ESC and a second polarity to the second electrostatic electrode of the ESC, where N is an integer

greater than one. During another one of the N portions of the treatment of the substrate, the method includes clamping the substrate by supplying the second polarity to the first electrostatic electrode of the ESC and the first polarity to the second electrostatic electrode of the ESC.

5 [0016] In other features, the treatment comprises deposition. The first electrostatic electrode and the second electrostatic electrode have a semicircular outer shape. The method includes striking plasma during the one of the N portions of the treatment; extinguishing the plasma between the one of the N portions and the another one of N portions of the treatment; and striking the plasma again during the another one of N
10 portions of the treatment.

[0017] In other features, the method includes de-clamping the substrate after extinguishing the plasma. The method includes clamping the substrate before striking the plasma during the another one of N portions of the treatment. $N = 2$.

[0018] A method for clamping substrates in a substrate processing tool includes
15 providing S processing chambers including S ESCs, where S an integer greater than one, wherein each of the S ESCs includes a baseplate, a top plate, and a bonding layer arranged between the baseplate and the top plate, and wherein the top plates of the S ESCs include first electrostatic electrodes and second electrostatic electrodes. During one of N portions of S treatments of S substrates in the S processing chambers, the
20 method includes clamping the S substrates in the S processing chambers, respectively, by supplying a first polarity to the first electrostatic electrodes of the S ESCs and a second polarity to the second electrostatic electrodes of the S ESCs, where N is an integer greater than one. During another one of the N portions of the S treatments of the S substrates, clamping the S substrates in the S processing chambers, respectively, by
25 supplying the second polarity to the first electrostatic electrodes of the S ESCs and the first polarity to the second electrostatic electrodes of the S ESCs.

[0019] In other features, the S treatments comprise deposition. In other features, the method includes striking plasma using the S plasma generators during the one of the N portions of the S treatments in the S processing chambers; extinguishing the plasma in
30 the S processing chambers between the one of the N portions and the another one of N portions; and striking the plasma in the S processing chambers during the another one of N portions of the S treatments.

[0020] In other features, the method includes de-clamping the S substrates after extinguishing the plasma. In other features, the method includes clamping the S substrates before striking the plasma during the another one of N portions of the S treatments. The first electrostatic electrodes and the second electrostatic electrodes in each of the S processing chambers are energized in a balanced configuration.

[0021] In other features, S is equal to four and the method includes arranging the S processing chambers in 2 by 2 array, and energizing the first electrostatic electrodes and the second electrostatic electrodes in each of the S processing chambers in a balanced configuration.

10 [0022] In other features, S is equal to four and the method includes arranging the S processing chambers in 2 by 2 array, and energizing the first electrostatic electrodes and the second electrostatic electrodes in each of the S processing chambers with facing electrodes in adjacent ones of the S processing chambers having opposite polarities.

15 [0023] In other features, S is equal to four and the method includes arranging the S processing chambers in 2 by 2 array, and orienting the first electrostatic electrodes and the second electrostatic electrodes in adjacent ones of the S processing chambers 90° relative to one another. N=2.

[0024] Further areas of applicability of the present disclosure will become apparent from the detailed description, the claims, and the drawings. The detailed description and specific examples are intended for purposes of illustration only and are not intended to limit the scope of the disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] The present disclosure will become more fully understood from the detailed description and the accompanying drawings, wherein:

25 [0026] FIG. 1 is a functional block diagram of an example of a substrate processing system including an ESC with electrostatic electrodes according to the present disclosure;

[0027] FIG. 2A is a plan view of an example of a ceramic top plate of the ESC including embedded electrostatic electrodes biased by DC voltages with a first polarity and a second polarity according to the present disclosure;

[0028] FIG. 2B is a plan view of the ceramic top plate of the ESC after swapping the first polarity and the second polarity of the electrostatic electrodes according to the present disclosure;

5 [0029] FIG. 3A is a plan view of an example of a semiconductor tool including multiple processing chambers with ESCs according to the present disclosure;

[0030] FIG. 3B is a plan view of the semiconductor tool after swapping the first polarity and the second polarity of the electrostatic electrodes of the processing chambers according to the present disclosure;

10 [0031] FIG. 4A is a plan view of another example of a semiconductor tool including multiple processing chambers with top plates including electrostatic electrodes that are balanced and swapped during the treatment according to the present disclosure;

[0032] FIG. 4B is a plan view of the semiconductor tool after swapping the first polarity and the second polarity of the electrostatic electrodes of the processing chambers according to the present disclosure;

15 [0033] FIG. 5 is a graph illustrating an example of the chucking voltage as a function of time according to the present disclosure;

[0034] FIG. 6 are graphs illustrating improved thickness nonuniformity of the substrate as a function of substrate radius after deposition without swapping/balancing and with swapping/balancing according to the present disclosure; and

20 [0035] FIG. 7 is a flowchart of an example of a method for controlling the electrostatic electrodes of the ESC during substrate processing according to the present disclosure.

[0036] In the drawings, reference numbers may be reused to identify similar and/or identical elements.

DETAILED DESCRIPTION

25 [0037] The present disclosure relates to systems and methods for controlling voltage output to a pair of electrostatic electrodes embedded in a top plate of an electrostatic chuck (ESC). During clamping in some processes, high DC voltages (e.g., 1000V) may be applied to the electrostatic electrodes. Due to side-to-side asymmetry of the ESC, the process may have nonuniformity such as imbalanced deposition thickness.

30 [0038] The systems and methods for controlling voltage output to a pair of electrostatic electrodes significantly reduce nonuniformity (e.g., a reduction in non-uniformity of 2 to

3%). In some examples, non-uniformity refers to thickness variations. For semiconductor tools with a single processing chamber, polarity swapping is performed. For example only, a deposition process with nonuniformity over 2.5 k Angstroms (kÅ) for a 26kÅ deposited film was reduced to less than 2 kÅ. For semiconductor tools with multiple processing chambers or stations, polarity swapping and/or polarity balancing can be performed to reduce nonuniformity in each station and to reduce station-to-station crosstalk.

[0039] During one portion of the treatment of the substrate, the controller outputs DC voltages with the same magnitude and opposite polarities to the pair of electrostatic electrodes. During another portion of the treatment of the same substrate, the controller swaps or reverses the polarities of the DC voltages supplied to the pair of electrostatic electrodes. The swapping of the DC voltages during the treatment of the substrate reduces processing nonuniformity (e.g., such as deposited film thickness). In some examples, the treatment includes chemical vapor deposition (CVD) or plasma-enhanced chemical vapor deposition (PECVD), although other treatments can be performed.

[0040] In some examples, the semiconductor tool includes a single processing chamber with an ESC including two electrostatic electrodes. In other examples, a semiconductor tool includes multiple processing chambers or stations arranged adjacent to one another. For example, four processing chambers are arranged in an array (e.g., rows and columns of a 2 x 2 array). In other examples, the semiconductor tool may include additional or fewer processing chambers that are arranged in other configurations. During the treatment of the substrate, the polarities of the DC voltages supplied to the electrostatic electrodes of the ESCs are swapped at the same time.

[0041] In examples including four processing chambers, the electrostatic electrodes of two of the processing chambers are oriented at a predetermined offset angle relative to a line parallel to the columns of the array. The electrostatic electrodes of the other two processing chambers are oriented at the predetermined offset angle relative to the line parallel to the rows of the array.

[0042] In some examples, the electrostatic electrodes in each of the processing chambers are also balanced. As used herein, the term balanced refers to a case where the electrostatic electrodes of each processing chamber in the semiconductor tool face (or substantially face as will be described below) electrostatic electrodes of adjacent neighboring processing chambers that have opposite polarities.

[0043] Referring now to FIG. 1, a substrate processing system 100 includes a processing chamber 102 including a gas distribution device 104 and an electrostatic chuck (ESC) 106. During operation, a substrate 108 is arranged on and clamped to the ESC 106. The ESC 106 includes a baseplate 110. In some examples, the baseplate 110
5 is made of a conducting material such as aluminum. The baseplate 110 supports a ceramic top plate 112, which may be made of ceramic or another plasma resistant material.

[0044] A bond layer 114 bonds the ceramic top plate 112 to the baseplate 110. The ceramic top plate 112 includes a pair of electrostatic electrodes 113 that are embedded
10 therein and that are energized and deenergized to clamp and unclamp, respectively, the substrate 108 on the ceramic top plate 112. The baseplate 110 may include one or more coolant channels 116 for flowing coolant through the baseplate 110 to control substrate temperature. In some examples, one or more edge rings 118 are arranged around the ESC 106 to shape the plasma.

[0045] A gas delivery system 130 includes one or more gas sources 132. The gas sources 132 supply one or more process gas mixtures. For a deposition process, the process gas mixture may include carrier gas, inert gases, deposition precursor gases, etc. For an etching process, the process gas mixture may include carrier gas, inert gases, etching gas, etc. The gas sources 132 are connected by flow metering devices 134 (e.g.,
20 mass flow controllers and valves) to a manifold 140. An output of the manifold 140 is fed to the gas distribution device 104.

[0046] In some examples, a vapor delivery system 170 includes one or more vapor delivery sources that supply vapor to the manifold 140 or connect to the gas distribution device 104 downstream from the manifold 140. In some examples, the vapor delivery
25 system 170 includes one or more ampoules 174, vaporizers 176, and flow metering devices 178 to controllably supply the vapor to the processing chamber.

[0047] In some examples, a temperature controller 142 is connected to heating elements 144 (e.g., thermal control elements (TCEs) or resistive heaters) arranged in the ceramic top plate 112. The temperature controller 142 may be used to supply power to
30 the heating elements 144 to control a temperature of the ESC 106 and the substrate 108 during processing. The temperature controller 142 also operates a coolant assembly 146 that controls coolant flow through the coolant channels 116. For example, the coolant assembly 146 may include a coolant pump and coolant reservoir (not shown). The

temperature controller 142 operates the coolant assembly 146 to selectively flow the coolant through the coolant channels 116 to cool the ESC 106.

5 [0048] A valve 150 and a pump 152 are connected to a gas line 148 (e.g., an exhaust gas line) and are used to control pressure within the processing chamber 102 and/or to evacuate reactants from the processing chamber 102. A plasma generator 154 includes a radio frequency (RF) source 156 to output RF voltage/power to a matching network 158. The matching network 158 matches the impedance of the RF source 156 to the impedance of the load including the processing chamber and plasma. A controller 160 may be used to monitor system parameters and to control components of the substrate
10 processing system 100 based on a recipe. One or more robots 161 may be used to deliver substrates onto, and remove substrates from, the ESC 106 through a port (not shown).

[0049] The gas distribution device 104 includes a gas plenum 182 that distributes gas from the gas delivery system 130 or vapor from the vapor delivery system 170 to gas
15 through holes 184 passing through an electrode 186 that is grounded. In some examples, the electrode 186 comprises a circular plate made of a conducting material that is shorted to ground.

[0050] Referring now to FIG. 2A, the ceramic top plate 112 of the ESC includes a first electrode 113A and a second electrode 113B. In some examples, the first electrode 113A
20 and a second electrode 113B have a semi-circular outer shape with flat edges facing one another (with a gap therebetween) and arcuate edges facing outwardly, although other shapes (e.g., rectangles for rectangular ESCs can be used).

[0051] During a first portion of a treatment in FIG. 2A, the first electrode 113A has a positive polarity (or negative polarity) and the second electrode 113B has a negative
25 polarity (or positive polarity). During a second portion of the treatment in FIG. 2B, the first electrode 113A has a negative polarity (or positive polarity) and the second electrode 113B has a positive polarity (or negative polarity).

[0052] In some examples, the first portion of the treatment corresponds to approximately the first half of the treatment and the second portion of the treatment corresponds to the
30 second half of the treatment. In other examples, the treatment is divided into N portions and the polarities are switched N times during the treatment (where N is an integer greater than one). In some examples, N is an even integer greater than two. As can be appreciated, a tradeoff is made between reduced nonuniformity and the cost of the time

required to extinguish the plasma, de-clamp the substrate, and re-clamp the substrate with the opposite polarity. In some examples, the treatment includes deposition of film onto the substrate 108, although other types of treatments can be performed either with or without plasma.

5 [0053] Referring now to FIGS. 3A and 3B, a semiconductor tool 200 includes multiple processing chambers 210-1, 210-2, 210-3, and 210-4. While four are shown, additional or fewer processing chambers can be used. In some examples, the processing chambers 210-1, 210-2, 210-3, and 210-4 are arranged in a 2 x 2 array with rows and columns. The processing chambers 210-1 and 210-3 and the processing chambers 210-2 and 210-4
10 are located in opposite corners of the array, respectively.

[0054] In some examples, the electrostatic electrodes of the processing chambers 210-1 and 210-3 are rotated 90° relative to the electrostatic electrodes of the processing chambers 210-2 and 210-4. In some examples, electrostatic electrodes of the processing chambers 210-1 and 210-3 are rotated counter-clockwise by a predetermined offset
15 angle relative to lines parallel to columns of the array. In some examples, electrostatic electrodes of the processing chambers 210-1 and 210-3 are rotated counter-clockwise by the predetermined offset angle relative to lines parallel to rows of the array. In some examples, the predetermined offset angle is in a range from 5° to 60°.

[0055] In FIG. 3A, during the first portion of the treatment, the electrodes 113-A1, 113-A2, 113-A3, and 113-A4 of the ceramic top plates 112-1, 112-2, 112-3, and 112-4,
20 respectively, have a first polarity (e.g., negative or positive polarity) and the electrodes 113-B1, 113-B2, 113-B3, and 113-B4 of the ceramic top plates 112-1, 112-2, 112-3, and 112-4, respectively, have a second polarity (e.g., positive or negative polarity).

[0056] In FIG. 3B, during the second portion of the treatment, the electrodes 113-A1, 113-A2, 113-A3, and 113-A4 of the ceramic top plates 112-1, 112-2, 112-3, and 112-4,
25 respectively, have the second polarity (e.g., positive or negative polarity) and the electrodes 113-B1, 113-B2, 113-B3, and 113-B4 of the ceramic top plates 112-1, 112-2, 112-3, and 112-4, respectively, have the first polarity (e.g., negative or positive polarity).

[0057] In the example illustrated in FIGS. 3A and 3B, the polarities of the electrostatic
30 electrodes are swapped but are not balanced. The electrostatic electrodes of the processing chamber substantially face electrodes from adjacent processing chambers having the same polarity. The electrodes substantially face one another since their relative positions are not mirrored due to the predetermined offset angle. For example,

the electrostatic electrode 113-A1 from the processing chamber 210-1 substantially faces the electrode 113-A4 from the processing chamber 210-4 and has the same polarity.

5 [0058] Referring now to FIGS. 4A to 4C, the electrostatic electrodes can be biased differently than in FIGS. 3A and 3B to balance the electrodes. In FIG. 4A, during the first portion of the treatment, the electrodes 113-A1, 113-A2, 113-A3, and 113-A4 of the ceramic top plates 112-1, 112-2, 112-3, and 112-4, respectively, have a first polarity (e.g., negative or positive polarity) and the electrodes 113-B1, 113-B2, 113-B3, and 113-B4 of the ceramic top plates 112-1, 112-2, 112-3, and 112-4, respectively, have a second polarity (e.g., positive or negative polarity).

10 [0059] In FIG. 4B, during the second portion of the treatment, the electrodes 113-A1, 113-A2, 113-A3, and 113-A4 of the ceramic top plates 112-1, 112-2, 112-3, and 112-4, respectively, have the second polarity (e.g., positive or negative polarity) and the electrodes 113-B1, 113-B2, 113-B3, and 113-B4 of the ceramic top plates 112-1, 112-2, 112-3, and 112-4, respectively, have the first polarity (e.g., negative or positive polarity).

15 [0060] In the example illustrated in FIGS. 4A and 4B, the polarities of the electrodes are balanced because the electrostatic electrodes of the processing chamber substantially face electrodes from the adjacent processing chambers that have the opposite polarity (rather than the same polarity as in FIGS. 3A and 3B). For example, the electrostatic electrode 113-A1 from the processing chamber 210-1 substantially faces and has a different polarity than the electrode 113-A4 from the processing chamber 210-4.

20 [0061] Referring now to FIG. 5, an example of DC voltages for the first polarity 260 and the second polarity 262 are shown. During the first portion of the treatment, the DC voltage of the first polarity increases from zero to a positive voltage peak 270 above a steady state positive voltage 272 and then falls to the steady state positive voltage 272.

25 The DC voltage of the first polarity remains at the steady state positive 272 voltage until the polarity swap occurs. During polarity swap, the DC voltage of the first polarity falls from the steady state positive voltage 272 to zero at 274 and remains at zero for a predetermined period. Then the DC voltage of the first polarity has a similar but inverted half cycle during the second portion of the treatment. The DC voltage of the second polarity is a mirror image of the DC voltage of the first polarity.

30 [0062] Referring now to FIG. 6, normalized thickness is shown as a function of substrate radius for deposition performed without swapping or balancing (on the left) and with

swapping and balancing (on the right). As can be seen, substrate processing with swapping and balancing (on the right) has decreased nonuniformity.

[0063] Referring now to FIG. 7, a flowchart of a method for controlling electrostatic clamping of one or more substrates on one or more ESCs during substrate processing is shown. At 308, the substrate(s) are delivered onto the ESC(s). At 310, substrate(s) are clamped by applying a first polarity to the first electrostatic electrode(s) of the ESC(s) and a second polarity to the second electrostatic electrode(s) of the ESC(s). At 314, a first portion of the treatment is performed. In some examples, plasma is struck. At 318, the method determines if the first portion is done. If not, the method returns to 314.

[0064] If 318 is true, the substrate is de-clamped at 322. If plasma is used, it is extinguished. At 326, the substrate(s) are clamped by applying the second polarity to the first electrostatic electrode(s) of the ESC(s) and the first polarity to the second electrostatic electrode(s) of the ESC(s). At 334, a second portion of the treatment is performed. If plasma is used, plasma is struck. At 336, the method determines whether the second portion is done. If not, the method returns to 334. If true, the substrate is de-clamped at 337. If plasma is used, the plasma is extinguished. At 338, the method determines whether the process is done. If false, the method returns to 310. If true, the method ends.

[0065] The foregoing description is merely illustrative in nature and is in no way intended to limit the disclosure, its application, or uses. The broad teachings of the disclosure can be implemented in a variety of forms. Therefore, while this disclosure includes particular examples, the true scope of the disclosure should not be so limited since other modifications will become apparent upon a study of the drawings, the specification, and the following claims. It should be understood that one or more steps within a method may be executed in different order (or concurrently) without altering the principles of the present disclosure. Further, although each of the embodiments is described above as having certain features, any one or more of those features described with respect to any embodiment of the disclosure can be implemented in and/or combined with features of any of the other embodiments, even if that combination is not explicitly described. In other words, the described embodiments are not mutually exclusive, and permutations of one or more embodiments with one another remain within the scope of this disclosure.

[0066] Spatial and functional relationships between elements (for example, between modules, circuit elements, semiconductor layers, etc.) are described using various terms,

including “connected,” “engaged,” “coupled,” “adjacent,” “next to,” “on top of,” “above,” “below,” and “disposed.” Unless explicitly described as being “direct,” when a relationship between first and second elements is described in the above disclosure, that relationship can be a direct relationship where no other intervening elements are present between the first and second elements, but can also be an indirect relationship where one or more intervening elements are present (either spatially or functionally) between the first and second elements. As used herein, the phrase at least one of A, B, and C should be construed to mean a logical (A OR B OR C), using a non-exclusive logical OR, and should not be construed to mean “at least one of A, at least one of B, and at least one of C.”

10 **[0067]** In some implementations, a controller is part of a system, which may be part of the above-described examples. Such systems can comprise semiconductor processing equipment, including a processing semiconductor tool or semiconductor tools, chamber or chambers, a platform, or platforms for processing, and/or specific processing components (a wafer pedestal, a gas flow system, etc.). These systems may be integrated with electronics for controlling their operation before, during, and after processing of a semiconductor wafer or substrate. The electronics may be referred to as the “controller,” which may control various components or subparts of the system or systems. The controller, depending on the processing requirements and/or the type of system, may be programmed to control any of the processes disclosed herein, including the delivery of processing gases, temperature settings (e.g., heating and/or cooling), pressure settings, vacuum settings, power settings, radio frequency (RF) generator settings, RF matching circuit settings, frequency settings, flow rate settings, fluid delivery settings, positional and operation settings, wafer transfers into and out of a semiconductor tool and other transfer semiconductor tools and/or load locks connected to or interfaced with a specific system.

20 **[0068]** Broadly speaking, the controller may be defined as electronics having various integrated circuits, logic, non-transitory memory, and/or software that receive instructions, issue instructions, control operation, enable cleaning operations, enable endpoint measurements, and the like. The integrated circuits may include chips in the form of firmware that store program instructions, digital signal processors (DSPs), chips defined as application specific integrated circuits (ASICs), and/or one or more microprocessors, or microcontrollers that execute program instructions (e.g., software). Program instructions may be instructions communicated to the controller in the form of various individual settings (or program files), defining operational parameters for carrying

out a particular process on or for a semiconductor wafer or to a system. The operational parameters may, in some embodiments, be part of a recipe defined by process engineers to accomplish one or more processing steps during the fabrication of one or more layers, materials, metals, oxides, silicon, silicon dioxide, surfaces, circuits, and/or dies of a wafer.

5 **[0069]** The controller, in some implementations, may be a part of or coupled to a computer that is integrated with the system, coupled to the system, otherwise networked to the system, or a combination thereof. For example, the controller may be in the “cloud” or all or a part of a fab host computer system, which can allow for remote access of the wafer processing. The computer may enable remote access to the system to monitor
10 current progress of fabrication operations, examine a history of past fabrication operations, examine trends or performance metrics from a plurality of fabrication operations, to change parameters of current processing, to set processing steps to follow a current processing, or to start a new process. In some examples, a remote computer (e.g., a server) can provide process recipes to a system over a network, which may
15 include a local network or the Internet. The remote computer may include a user interface that enables entry or programming of parameters and/or settings, which are then communicated to the system from the remote computer. In some examples, the controller receives instructions in the form of data, which specify parameters for each of the processing steps to be performed during one or more operations. It should be understood
20 that the parameters may be specific to the type of process to be performed and the type of semiconductor tool that the controller is configured to interface with or control. Thus, as described above, the controller may be distributed, such as by comprising one or more discrete controllers that are networked together and working towards a common purpose, such as the processes and controls described herein. An example of a distributed
25 controller for such purposes would be one or more integrated circuits on a chamber in communication with one or more integrated circuits located remotely (such as at the platform level or as part of a remote computer) that combine to control a process on the chamber.

[0070] Without limitation, example systems may include a plasma etch chamber or
30 module, a deposition chamber or module, a spin-rinse chamber or module, a metal plating chamber or module, a clean chamber or module, a bevel edge etch chamber or module, a physical vapor deposition (PVD) chamber or module, a chemical vapor deposition (CVD) chamber or module, an atomic layer deposition (ALD) chamber or module, an atomic layer etch (ALE) chamber or module, an ion implantation chamber or

module, a track chamber or module, and any other semiconductor processing systems that may be associated or used in the fabrication and/or manufacturing of semiconductor wafers.

- [0071]** As noted above, depending on the process step or steps to be performed by the semiconductor tool, the controller might communicate with one or more of other semiconductor tool circuits or modules, other semiconductor tool components, cluster semiconductor tools, other semiconductor tool interfaces, adjacent semiconductor tools, neighboring semiconductor tools, semiconductor tools located throughout a factory, a main computer, another controller, or semiconductor tools used in material transport that bring containers of wafers to and from semiconductor tool locations and/or load ports in a semiconductor manufacturing factory.

CLAIMS

What is claimed is:

1. A substrate processing system, comprising:
an electrostatic chuck (ESC) including a baseplate, a top plate, and a bonding
5 layer arranged between the baseplate and the top plate,
wherein the top plate includes a first electrostatic electrode and a second
electrostatic electrode embedded therein; and
a controller configured to:
during one of N portions of a treatment of a substrate, clamp a substrate by
10 supplying a first polarity to the first electrostatic electrode of the ESC and a second
polarity to the second electrostatic electrode of the ESC, where N is an integer greater
than one; and
during another one of the N portions of the treatment of the substrate clamp
the substrate by supplying the second polarity to the first electrostatic electrode of the
15 ESC and the first polarity to the second electrostatic electrode of the ESC.
2. The substrate processing system of claim 1, wherein the treatment comprises
deposition.
- 20 3. The substrate processing system of claim 1, wherein the first electrostatic
electrode and the second electrostatic electrode have a semicircular outer shape.
4. The substrate processing system of claim 1, further comprising a plasma
generator configured to generate plasma, wherein the controller is configured to:
25 strike plasma during the one of the N portions of the treatment;
extinguish the plasma between the one of the N portions and the another one of
N portions of the treatment; and
strike the plasma again during the another one of N portions of the treatment.
- 30 5. The substrate processing system of claim 4, wherein the controller is configured
to de-clamp the substrate after extinguishing the plasma.

6. The substrate processing system of claim 5, wherein the controller is configured to clamp the substrate before striking the plasma during the another one of N portions of the treatment.
- 5 7. The substrate processing system of claim 1, wherein $N = 2$.
8. A substrate processing tool, comprising:
S processing chambers including S ESCs, where S an integer greater than one;
wherein each of the S ESCs includes a baseplate, a top plate, and a bonding layer
10 arranged between the baseplate and the top plate,
wherein the top plates of the S ESCs include first electrostatic electrodes and
second electrostatic electrodes; and
a controller configured to:
during one of N portions of S treatments of S substrates in the S processing
15 chambers, clamp the S substrates in the S processing chambers, respectively, by
supplying a first polarity to the first electrostatic electrodes of the S ESCs and a second
polarity to the second electrostatic electrodes of the S ESCs, where N is an integer
greater than one; and
during another one of the N portions of the S treatments of the S substrates,
20 clamp the S substrates in the S processing chambers, respectively, by supplying the
second polarity to the first electrostatic electrodes of the S ESCs and the first polarity to
the second electrostatic electrodes of the S ESCs.
9. The substrate processing tool of claim 8, wherein the S treatments comprise
25 deposition.

10. The substrate processing tool of claim 8, further comprising S plasma generators configured to generate plasma in the S processing chambers, wherein the controller is configured to:

5 strike plasma using the S plasma generators during the one of the N portions of the S treatments in the S processing chambers;

extinguish the plasma in the S processing chambers between the one of the N portions and the another one of N portions; and

strike the plasma in the S processing chambers during the another one of N portions of the S treatments.

10

11. The substrate processing tool of claim 10, wherein the controller is configured to de-clamp the S substrates after extinguishing the plasma.

12. The substrate processing tool of claim 10, wherein the controller is configured to clamp the S substrates before striking the plasma during the another one of N portions of the S treatments.

13. The substrate processing tool of claim 8, wherein the first electrostatic electrodes and the second electrostatic electrodes in each of the S processing chambers are energized in a balanced configuration.

14. The substrate processing tool of claim 8, wherein:
S is equal to four,
the S processing chambers are arranged in 2 by 2 array, and
25 the first electrostatic electrodes and the second electrostatic electrodes in each of the S processing chambers are energized in a balanced configuration.

15. The substrate processing tool of claim 8, wherein:
S is equal to four,
30 the S processing chambers are arranged in 2 by 2 array, and
the first electrostatic electrodes and the second electrostatic electrodes in each of the S processing chambers are energized with facing electrodes in adjacent ones of the S processing chambers having opposite polarities.

16. The substrate processing tool of claim 8, wherein:
S is equal to four,
the S processing chambers are arranged in 2 by 2 array, and
the first electrostatic electrodes and the second electrostatic electrodes in
5 adjacent ones of the S processing chambers are rotated 90° relative to one another.
17. The substrate processing tool of claim 8, wherein N = 2.
18. A method for clamping a substrate in a substrate processing system, comprising:
10 providing an electrostatic chuck (ESC) including a baseplate, a top plate, and a bonding layer arranged between the baseplate and the top plate, wherein the top plate includes a first electrostatic electrode and a second electrostatic electrode embedded therein;
during one of N portions of a treatment of a substrate, clamping a substrate by
15 supplying a first polarity to the first electrostatic electrode of the ESC and a second polarity to the second electrostatic electrode of the ESC, where N is an integer greater than one; and
during another one of the N portions of the treatment of the substrate, clamping the substrate by supplying the second polarity to the first electrostatic electrode of the
20 ESC and the first polarity to the second electrostatic electrode of the ESC.
19. The method of claim 18, wherein the treatment comprises deposition.
20. The method of claim 18, wherein the first electrostatic electrode and the second
25 electrostatic electrode have a semicircular outer shape.
21. The method of claim 18, further comprising:
striking plasma during the one of the N portions of the treatment;
extinguishing the plasma between the one of the N portions and the another one
30 of N portions of the treatment; and
striking the plasma again during the another one of N portions of the treatment.
22. The method of claim 21, further comprising de-clamping the substrate after extinguishing the plasma.

23. The method of claim 22, further comprising clamping the substrate before striking the plasma during the another one of N portions of the treatment.

5 24. The method of claim 18, wherein $N = 2$.

25. A method for clamping substrates in a substrate processing tool, comprising:
providing S processing chambers including S ESCs, where S an integer greater than one, wherein each of the S ESCs includes a baseplate, a top plate, and a bonding
10 layer arranged between the baseplate and the top plate, and wherein the top plates of the S ESCs include first electrostatic electrodes and second electrostatic electrodes;

during one of N portions of S treatments of S substrates in the S processing chambers, clamping the S substrates in the S processing chambers, respectively, by supplying a first polarity to the first electrostatic electrodes of the S ESCs and a second
15 polarity to the second electrostatic electrodes of the S ESCs, where N is an integer greater than one; and

during another one of the N portions of the S treatments of the S substrates, clamping the S substrates in the S processing chambers, respectively, by supplying the second polarity to the first electrostatic electrodes of the S ESCs and the first polarity to
20 the second electrostatic electrodes of the S ESCs.

26. The method of claim 25, wherein the S treatments comprise deposition.

27. The method of claim 26, further comprising:
25 striking plasma using S plasma generators during the one of the N portions of the S treatments in the S processing chambers;

extinguishing the plasma in the S processing chambers between the one of the N portions and the another one of N portions; and

striking the plasma in the S processing chambers during the another one of N
30 portions of the S treatments.

28. The method of claim 27, further comprising de-clamping the S substrates after extinguishing the plasma.

29. The method of claim 28, further comprising clamping the S substrates before striking the plasma during the another one of N portions of the S treatments.
30. The method of claim 26, wherein the first electrostatic electrodes and the second
5 electrostatic electrodes in each of the S processing chambers are energized in a balanced configuration.
31. The method of claim 26, wherein S is equal to four and further comprising:
arranging the S processing chambers in 2 by 2 array; and
10 energizing the first electrostatic electrodes and the second electrostatic electrodes in each of the S processing chambers in a balanced configuration.
32. The method of claim 26, wherein S is equal to four and further comprising:
arranging the S processing chambers in 2 by 2 array; and
15 energizing the first electrostatic electrodes and the second electrostatic electrodes in each of the S processing chambers with facing electrodes in adjacent ones of the S processing chambers having opposite polarities.
33. The method of claim 26, wherein S is equal to four and further comprising:
20 arranging the S processing chambers in 2 by 2 array; and
orienting the first electrostatic electrodes and the second electrostatic electrodes in adjacent ones of the S processing chambers 90° relative to one another.
34. The method of claim 26, wherein N = 2.