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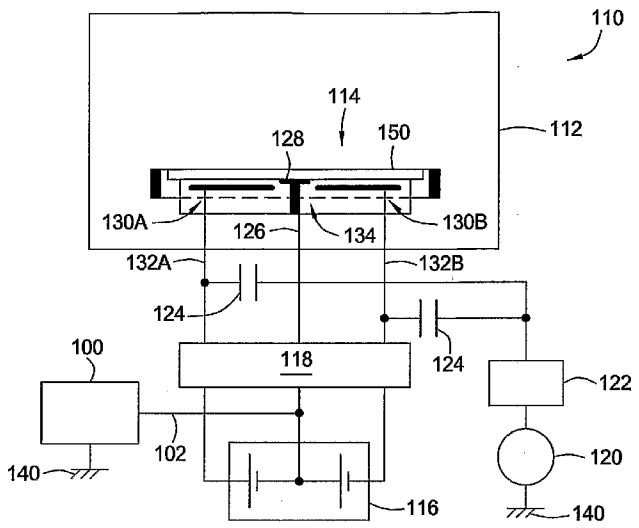
(54) **Title:** METHOD AND APPARATUS FOR IN-SITU SUBSTRATE SURFACE ARC DETECTION



(57) **Abstract:** Embodiments of a method and apparatus for in-situ substrate surface arc detection are provided herein. In one embodiment, an apparatus for detecting arcing on the surface of a substrate on an electrostatic chuck, having an electrostatic chucking assembly, disposed within a semiconductor processing chamber includes a voltage divider having an input configured to receive an input signal from the electrostatic chucking assembly representative of a voltage on a surface of a substrate; and a monitoring circuit coupled to the voltage divider for generating an output signal indicative of whether arcing has occurred on the surface of a substrate.

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METHOD AND APPARATUS FOR IN-SITU SUBSTRATE SURFACE ARC DETECTION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims benefit of United States Provisional Patent Application serial no. 60/701,316, filed July 21, 2005 and entitled, "METHOD AND APPARATUS FOR IN-SITU SUBSTRATE SURFACE ARC DETECTION," which is hereby incorporated by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] The present invention generally relates to processing substrates in semiconductor processing systems and, more particularly, to detecting arcing on the surface of the substrate within the process chamber.

Description of the Related Art

[0003] Electrostatic chucks are often utilized to secure substrates to a substrate support pedestal disposed in a process chamber during processing of semiconductor substrates. The electrostatic chuck creates an electrostatic force on the surface of a substrate in order to clamp the substrate securely to the substrate support pedestal. However, during processing, it has been observed that arcing may occur between the surface of the substrate and other components within the semiconductor processing chamber, for example, deposition rings, process kits, and the like.

[0004] The arcing on the surface of the substrate causes many problems. For example, the discharge of the arc may render the substrate unsuitable for further processing. In addition, the arcing reduces the potential accumulated on the surface of the substrate, thereby reducing the clamping force between the substrate and the electrostatic chuck. This may result in the substrate coming loose from the chuck. In addition, backside gases may leak into the chamber due to the reduced clamping force, potentially causing contamination within the processing chamber.

[0005] Therefore a need exists for detecting the occurrence of arcing on the surface of the substrate.

SUMMARY OF THE INVENTION

[0006] The present invention provides methods and apparatus for detecting arcing on the surface of a substrate in a semiconductor substrate process chamber. In one embodiment, an apparatus for detecting arcing on the surface of a substrate on an electrostatic chuck, having an electrostatic chucking assembly, disposed within a semiconductor processing chamber includes a voltage divider having an input configured to receive an input signal from the electrostatic chucking assembly representative of a voltage on a surface of a substrate; and a monitoring circuit coupled to the voltage divider for generating an output signal indicative of whether arcing has occurred on the surface of a substrate.

[0007] In another embodiment, an apparatus for detecting arcing on the surface of a substrate disposed within a semiconductor processing chamber includes an electrostatic chuck having an electrostatic chucking assembly; a first power supply coupled to the electrostatic chucking assembly of the electrostatic chuck for providing a clamping voltage to the electrostatic chuck; and an arc detection device coupled between the first power supply and the electrostatic chucking assembly.

[0008] In another aspect of the invention, a method for detecting arcing on the surface of a substrate in a semiconductor substrate processing chamber is provided. In one embodiment, the method includes receiving a first signal from an electrostatic chucking assembly of an electrostatic chuck indicating the DC bias voltage on the substrate surface; and comparing the first signal to a predetermined threshold value to determine whether arcing occurred on the surface of the substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] So that the manner in which the above recited features, advantages and objects of the present invention are attained and can be understood in

detail, a more particular description of the invention, briefly summarized above, may be had by reference to the embodiments thereof which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0010] Figure 1 depicts an exemplary block diagram of a plasma enhanced semiconductor processing chamber having an arc detection device.

[0011] Figure 2 is a block diagram of one embodiment of an arc detection device.

[0012] Figure 3 is a graph of the substrate bias voltage before and after the occurrence of surface arcing.

[0013] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures.

DETAILED DESCRIPTION

[0014] The present invention is a method and apparatus for detecting the occurrence of arcing on the surface of a substrate disposed on an electrostatic chuck in a semiconductor processing chamber. In one embodiment, the present invention utilizes an arc detection device that measures changes in the wafer surface DC bias voltage. Such a voltage change is indicative of the occurrence of arcing.

[0015] Figure 1 depicts a processing system 110 having an arc detection device 100 suitable for detecting the occurrence of arcing on the surface of a substrate 150. The processing system 110 generally includes a process chamber 112 having an electrostatic chuck 114 disposed therein for supporting a substrate 150. In one example, the processing system 110 is a PVD chamber, such as an EnCoRell or eSIP PVD chamber, both of which are available from Applied Materials, Inc., of Santa Clara, California. However, it is contemplated that the arc detection device 100 may be utilized in other systems for processing substrates utilizing electrostatic chucks as well.

[0016] The electrostatic chuck 114 includes an electrostatic chucking assembly 134. The electrostatic chucking assembly 134 comprises at least one electrode 130 coupled to a power supply 116 (*i.e.*, the electrostatic chuck 134 may be a monopolar electrostatic chuck, a bipolar electrostatic chuck, or the like). In the embodiment depicted in Figure 1, two electrodes 130_A and 130_B are coupled to the power supply 116 via lines 132_A and 132_B. In one embodiment, the power supply 116 is a DC power supply. The electrostatic chuck 114 may further have a contact pad 128 formed on a substrate support surface of the electrostatic chuck 114 for contacting the backside of the substrate 150 disposed thereon. The contact pad 128 is connected to the power supply 116 via a center tap 126.

[0017] An RF power supply 120 is provided to couple RF power to the chamber 112 during processing to form a plasma within the chamber 112. In one embodiment, the RF power supply 120 is coupled to the electrodes 130_A and 130_B of the electrostatic chuck 114 through a pair of RF coupling capacitors 124. A match circuit 122 is disposed between the RF power supply 120 and the electrostatic chuck 114 to match the impedance of the RF signal to that of the plasma during processing. The RF power supply 120 is further coupled to a chamber ground 140.

[0018] An RF filter 118 is positioned between the RF power supply 120 and the power supply 116. In one embodiment, the arc detection device 100 is coupled by a line 102 to the center tap 126 of the power supply 116 at a node disposed between the power supply 116 and the RF filter 118. The arc detection device 100 is also coupled to the chamber ground 140. Optionally, the arc detection device 100 may be integrated into the power supply 116 of the electrostatic chuck 114.

[0019] Figure 2 depicts a block diagram of one embodiment of the arc detection device 100. In the embodiment depicted in Figure 2, the arc detection device 100 includes a voltage divider 202 and a monitoring circuit 204. In one embodiment, the voltage divider 202 includes three resistors, R1, R2, and R3, connected in series between an input (line 102) and ground 140. Resistors R1 and R2 are high voltage resistors suitable for use receiving the

bias signal from line 102. The resistor R3 may be a lower voltage rated resistor. A transient voltage suppressor 206 is coupled in parallel between ground 140 and a node disposed between resistors R1 and R2. The arc detection device 100 can withstand high DC bias voltage.

[0020] In one embodiment, the monitoring circuit 204 includes a buffer 208 an isolation amplifier 210 and a comparator 212 coupled together in series. The buffer 208 is coupled to a tap from the node disposed between resistors R2 and R3 in the voltage divider 202. The comparator 212 is coupled to a switch 216 having a first output 224 and a second output 226. A threshold set point adjuster 214 is coupled to the comparator 212 for adjusting and selecting the desired voltage at which the switch 216 switches between the first output 224 and the second output 226. In one embodiment, the threshold set point adjuster 214 is a potentiometer.

[0021] A power source 218 is coupled to the monitoring circuit 204 of the arc detection device 100 to supply power thereto. A readback device 220 is coupled to a node disposed between the isolation amplifier 210 and the comparator 212. The readback device 220 is any device suitable for monitoring, indicating, recording, or operating on a signal indicative of the voltage signal coming from the power source 116 via line 102. In one embodiment, the readback device 220 is a display for displaying the voltage setting of the power supply 116. For example, the readback device 220 may be the display of a controller (not shown) that controls the processing system 110. Alternatively, the readback device 220 may be a controller, such as the controller that controls the processing system 110.

[0022] Table 1, below, lists examples of various details of certain embodiments of the arc detection device 100.

Variable	**Example**
Maximum voltage	about 3000 V
Maximum input bias voltage	about -750 V
Maximum operation bias voltage	about -500 V
Analog output readback voltage	0 to about -10 V
Input/Output ratio	about 50:1
Input/output isolation voltage	about 1500 Vrms, about 2121 V DC

Input impedance	about 10 MΩ
Analog readback accuracy	less than about 0.5% FS
Comparator output	about 24 V, 0.5 A relay contact
Potentiometer threshold setting	DC bias/setting ratio of about 80:1
Transient suppression	about 1000 W, 1 A @1 mS surge; leak current less than about 75 μA @750 V DC bias and less than about 1 mA @800 V DC bias
Power	about +15 V, 0.1 A

Table 1

[0023] In operation, the arc detection device 100 receives an input signal from the center tap 126 via line 102. The input signal is divided and reduced by the voltage divider 202 and coupled to the monitoring circuit 204. In the monitoring circuit 204, the signal is then conditioned and coupled to the comparator 212 where it is compared with a level set by the threshold set point adjuster 214. If the DC bias voltage is lower than the preselected threshold, the switch 216 routes the signal to the first output 224. However, if the DC bias is higher than the preselected threshold, then the switch 216 routes the signal to the second output 226.

[0024] The first and second outputs 224, 226 may be connected to a display indicia that indicates the level of the DC bias voltage on the surface of the substrate 150. In one example, the signal fed through the first output 224 may activate a green LED or some other signal indicating that the voltage potential on the substrate 150 is above the threshold and that, therefore, no surface arcing on the substrate 150 has occurred. When the DC bias voltage on the substrate 150 drops to a point lower than the threshold, the switch routes the signal through the second output 226, which may activate a red LED or some other signal indicating that surface arcing on the substrate 150 has occurred. It is contemplated that signaling indicia other than LEDs or displays may be utilized in connection with the arc detection device 100. For example, the respective signals may fed directly into a processor or other device that utilizes the signal to make appropriate corrections or other predetermined actions based upon the detection of substrate arcing.

[0025] It has been observed that the average voltage level on the surface of the substrate drops by approximately 40 percent after an arcing event occurs. Figure 3 is an illustrative depiction of a graph 300 summarizing those observations and showing the difference in levels of voltage depending upon whether surface arcing occurs on the substrate or not. The graph 300 represents the substrate surface potential in Volts (axis 304) versus time (axis 302). The voltage measured on the surface of a substrate during processing is represented by a line 320. As can be seen from the graph 300, the substrate surface remains near a first average voltage level 306 during processing until a time a 310 – corresponding to the occurrence of substrate arcing – at which point the voltage drops to a second average voltage level 308. The second average voltage level 308 is approximately 40 percent lower than the first average voltage level 306. Due to the severity of the drop in the average voltage level, the arc detection device 100 may be advantageously utilized to accurately and repeatedly detect the occurrence of substrate arcing.

[0026] Thus, an arc detection device and method for use have been provided that enables repeated accurate detection of substrate surface arcing by measuring the changes of the wafer surface DC bias voltage. The arc detection device may be directly connected to, and may be integrated with, the center tap of the electrostatic chuck power supply.

[0027] While the foregoing is directed to the illustrative embodiment of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the basic scope thereof is defined by the appended claims.

Claims

1. Apparatus for detecting arcing on the surface of a substrate on an electrostatic chuck, having an electrostatic chucking assembly, disposed within a semiconductor processing chamber, comprising:

a voltage divider having an input configured to receive an input signal from the electrostatic chucking assembly representative of a voltage on a surface of a substrate; and

a monitoring circuit coupled to the voltage divider for generating an output signal indicative of whether arcing has occurred on the surface of a substrate.

2. The apparatus of claim 1, wherein the voltage divider is further configured to reduce a voltage of the input signal.

3. The apparatus of claim 1, wherein the voltage divider further comprises:

a transient voltage suppressor.

4. The apparatus of claim 1, wherein the monitoring circuit further comprises:

a comparator configured to receive the input signal and provide the output signal dependent upon a variable set point.

5. The apparatus of claim 4, further comprising:

a threshold set point adjuster coupled to the comparator for adjusting and selecting the variable set point.

6. The apparatus of claim 4, further comprising:

a buffer; and

an isolation amplifier coupled in series between the comparator and the voltage divider.

7. The apparatus of claim 4, further comprising:

a switch coupled to and controlled by the comparator and having a first output and a second output.

8. The apparatus of claim 7, further comprising:

at least one display indicia coupled to the first and the second output and configured to indicate whether arcing has occurred on the surface of a substrate.

9. The apparatus of claim 1, further comprising:

a power source coupled to the monitoring circuit.

10. The apparatus of claim 1, further comprising:

a readback device coupled to monitoring circuit and configured to monitor, indicate, record, or operate on a signal indicative of the voltage of the input signal.

11. The apparatus of claim 1,

wherein the voltage divider further comprises:

a first, a second, and a third resistor coupled in series between the input of the voltage divider and ground, wherein the first and the second resistors comprise high voltage resistors suitable for receiving the input signal; and

a transient voltage suppressor coupled in parallel between ground and a node disposed between the first and second resistors; and

wherein the monitoring circuit further comprises:

a comparator configured to receive the input signal and provide the output signal dependent upon a variable set point;

a threshold set point adjuster coupled to the comparator for adjusting and selecting the variable set point; and

a switch coupled to and controlled by the comparator and having a first output and a second output.

12. Apparatus for detecting arcing on the surface of a substrate disposed within a semiconductor processing chamber, comprising:

an electrostatic chuck having an electrostatic chucking assembly;

a first power supply coupled to the electrostatic chucking assembly of the electrostatic chuck for providing a clamping voltage to the electrostatic chuck; and

an arc detection device coupled between the first power supply and the electrostatic chucking assembly.

13. The apparatus of claim 13, wherein the electrostatic chucking assembly further comprises:

a contact pad disposed in an upper surface of the electrostatic chuck and configured to contact a backside of the substrate during operation.

14. The apparatus of claim 13, where in the contact pad is coupled to the first power supply.

15. The apparatus of claim 12, wherein the first power supply is a DC power supply.

16. The apparatus of claim 12, further comprising:

an RF power supply coupled to the process chamber.

17. The apparatus of claim 16, further comprising:

an RF filter disposed between the first power supply and the RF power supply.

18. The apparatus of claim 17, wherein the arc detection device is coupled between the RF filter and the first power supply.

19. The apparatus of claim 12, wherein the arc detection device further comprises:

a voltage divider having an input configured to receive an input signal from the electrostatic chucking assembly representative of a voltage on a surface of a substrate; and

a monitoring circuit coupled to the voltage divider for generating an output signal indicative of whether arcing has occurred on the surface of a substrate.

20. The apparatus of claim 19, wherein the voltage divider further comprises:

a plurality of resistors coupled in series between the input of the voltage divider and ground, wherein at least one of the plurality of resistors comprises a high voltage resistor suitable for receiving the input signal; and

a transient voltage suppressor coupled in parallel between ground and at least one of the plurality of resistors.

21. The apparatus of claim 19, wherein the monitoring circuit further comprises:

a comparator configured to receive the input signal and provide the output signal dependent upon a variable set point;

a threshold set point adjuster coupled to the comparator for adjusting and selecting the variable set point; and

a switch coupled to and controlled by the comparator and having a first output and a second output.

22. The apparatus of claim 19, further comprising:

at least one display indicia coupled to the monitoring circuit and configured to indicate whether arcing has occurred on the surface of the substrate.

23. The apparatus of claim 19, further comprising:

a power source coupled to the monitoring circuit.

24. The apparatus of claim 19, wherein the electrostatic chuck comprises a monopolar electrostatic chuck.

25. The apparatus of claim 19, wherein the electrostatic chuck comprises a bipolar electrostatic chuck.

26. A method for detecting arcing on the surface of a substrate in a semiconductor substrate processing chamber, comprising:

receiving a first signal from an electrostatic chucking assembly of an electrostatic chuck indicating the DC bias voltage on the substrate surface; and

comparing the first signal to a predetermined threshold value to determine whether arcing occurred on the surface of the substrate.

27. The method of claim 26, further comprising:

reducing and conditioning the first signal prior to the comparing step.

28. The method of claim 26, further comprising:

routing a second signal in response to whether the first signal is greater than or less than the threshold value.

29. The method of claim 29, further comprising:

routing the second signal to a display indicia to indicate whether or not surface arcing occurred.

30. The method of claim 29, wherein the routing step further comprises:

routing the second signal to a first LED to indicate that surface arcing has occurred and routing the second signal to a second LED to indicate that surface arcing has not occurred.

31. The method of claim 26, wherein the receiving and comparing steps are performed in an arc detection device coupled to the electrostatic chucking assembly.

32. The method of claim 26, wherein the threshold value is adjustable.

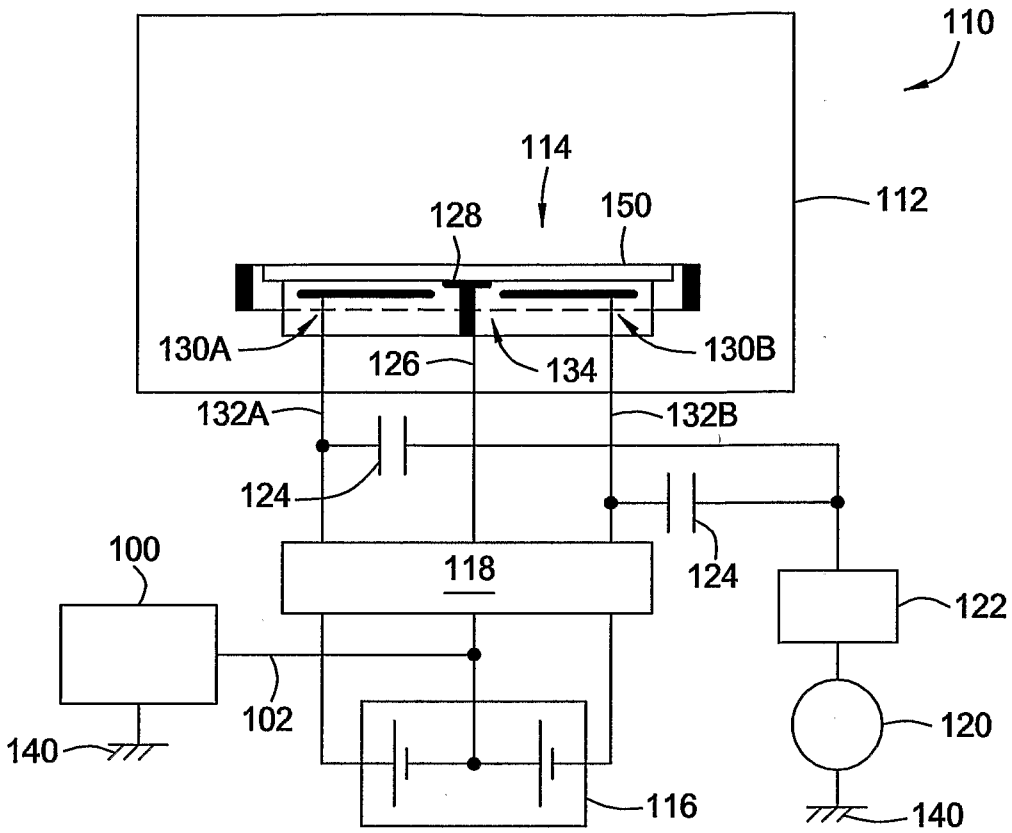
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FIG. 1

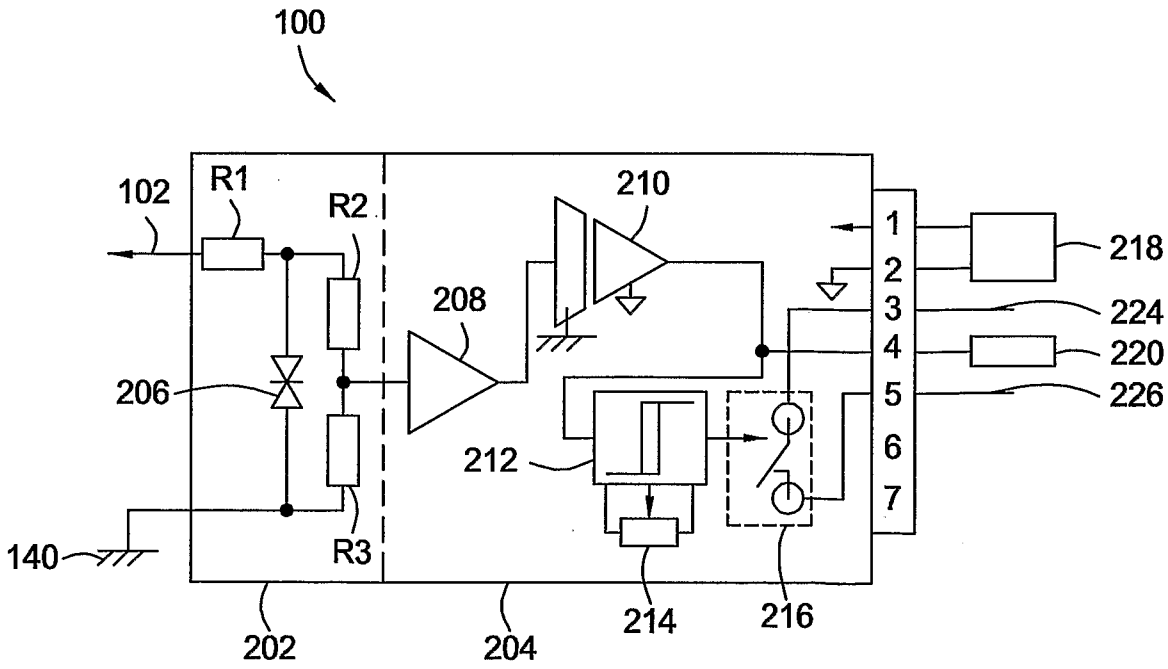
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FIG. 2

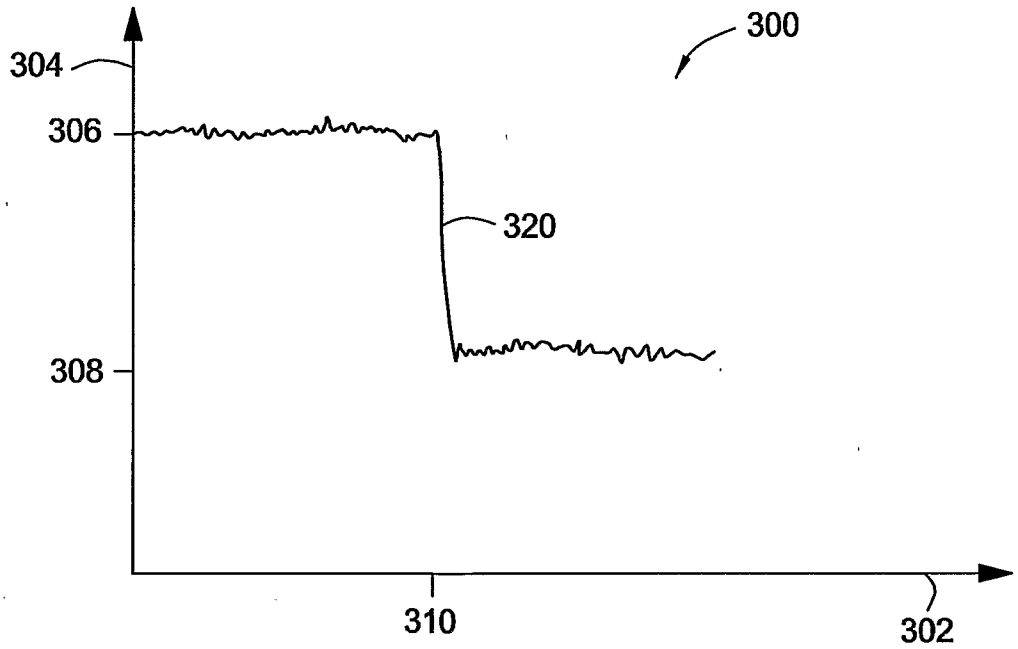

FIG. 3