



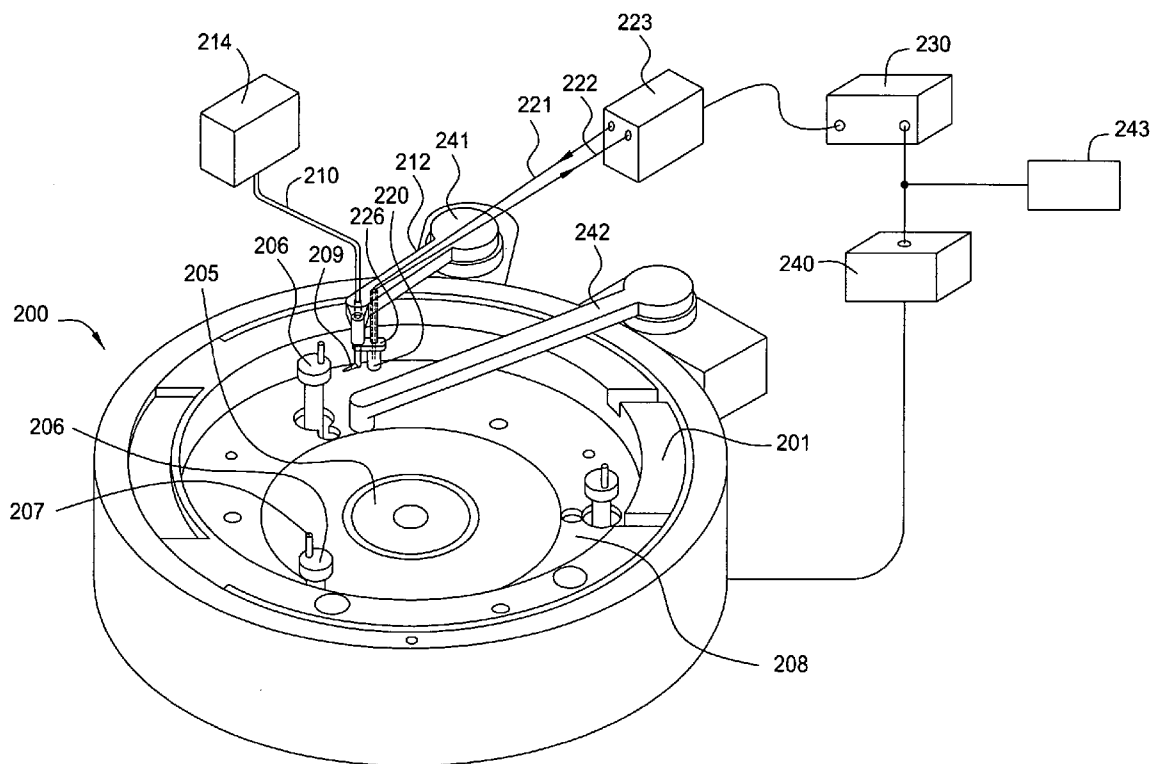
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(19) **United States**(12) **Patent Application Publication****Chen et al.**(10) **Pub. No.: US 2007/0209684 A1**(43) **Pub. Date: Sep. 13, 2007**(54) **COPPER DEPOSITION CHAMBER HAVING
INTEGRATED BEVEL CLEAN WITH EDGE
BEVEL REMOVAL DETECTION****Publication Classification**(51) **Int. Cl.**
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134/153; 134/902**(75) Inventors: **Chen-An Chen**, Milpitas, CA (US);
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HOUSTON, TX 77056 (US)(73) Assignee: **APPLIED MATERIALS, INC.**(21) Appl. No.: **11/369,590**(22) Filed: **Mar. 7, 2006**(57) **ABSTRACT**

Embodiments of the invention generally provide apparatus and method for detecting and controlling edge bevel removal of a semiconductor substrate. One embodiment of the present invention provides an apparatus for inspecting a rotating substrate. The apparatus comprises a substrate support configured to support the rotating substrate on a back side and rotate the substrate about a central axis, and a sensor positioned above the substrate support, the sensor being configured to inspect a front side of the rotating substrate while moving simultaneously radially across the substrate.



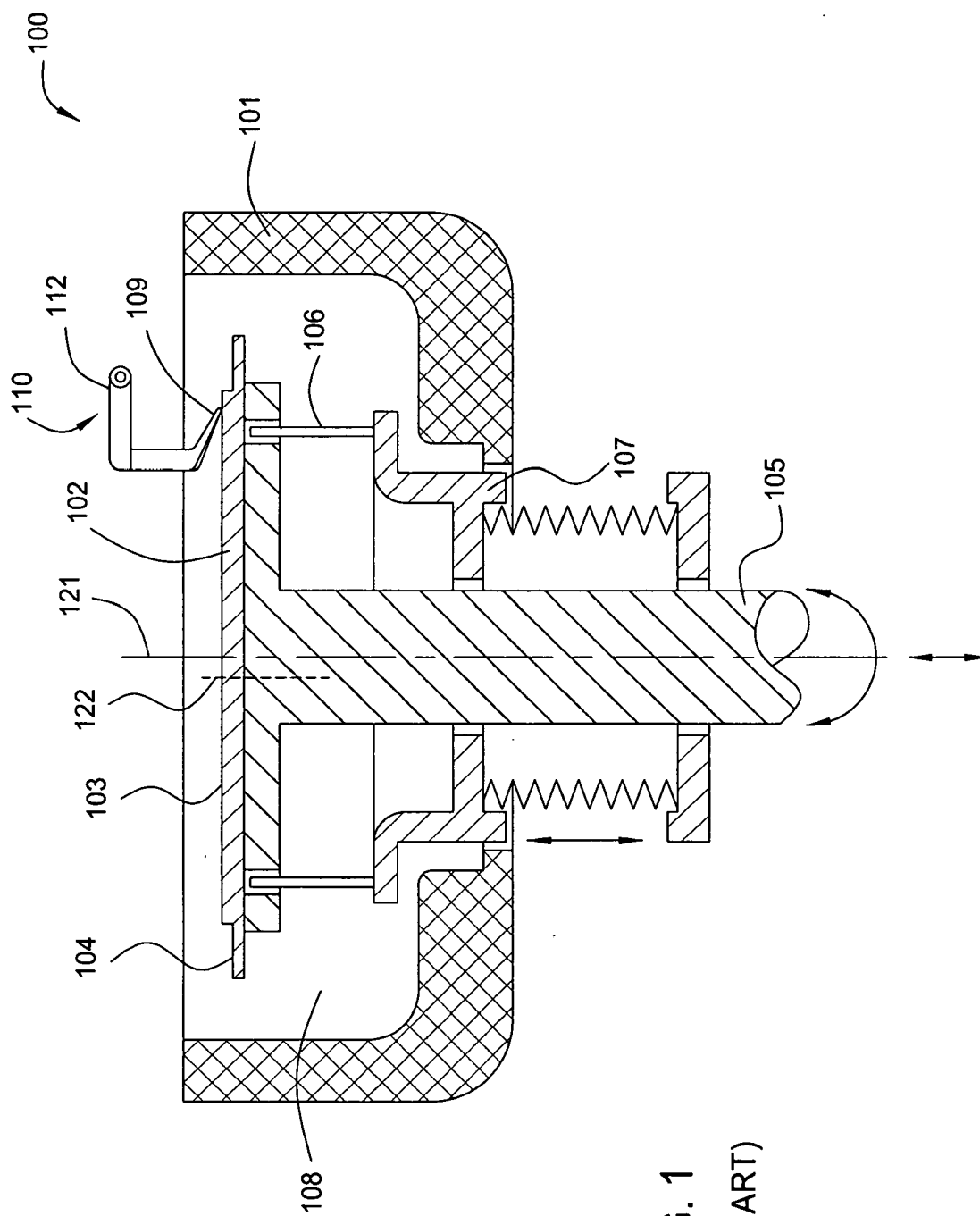


FIG. 1
(PRIOR ART)

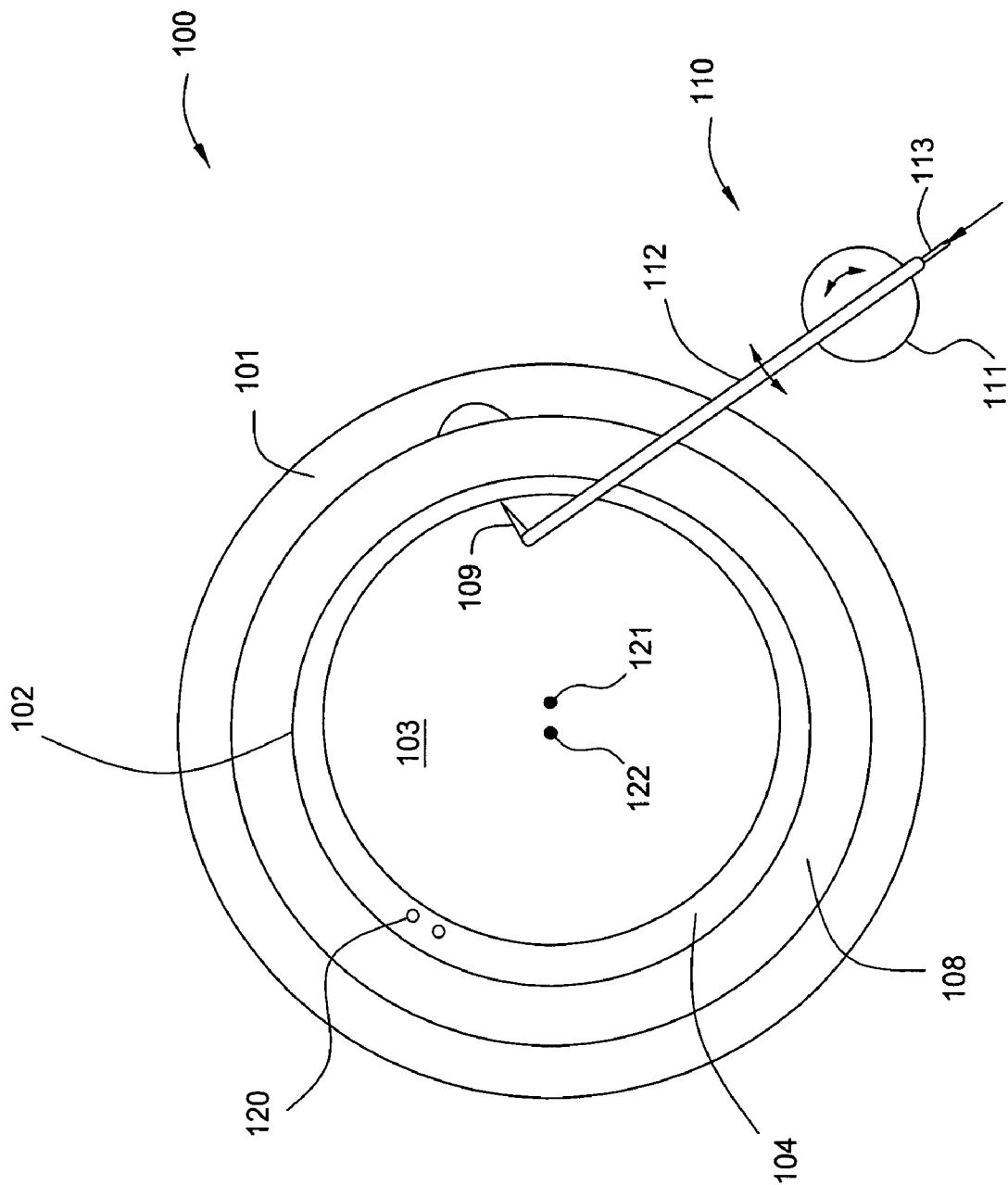


FIG. 2
(PRIOR ART)

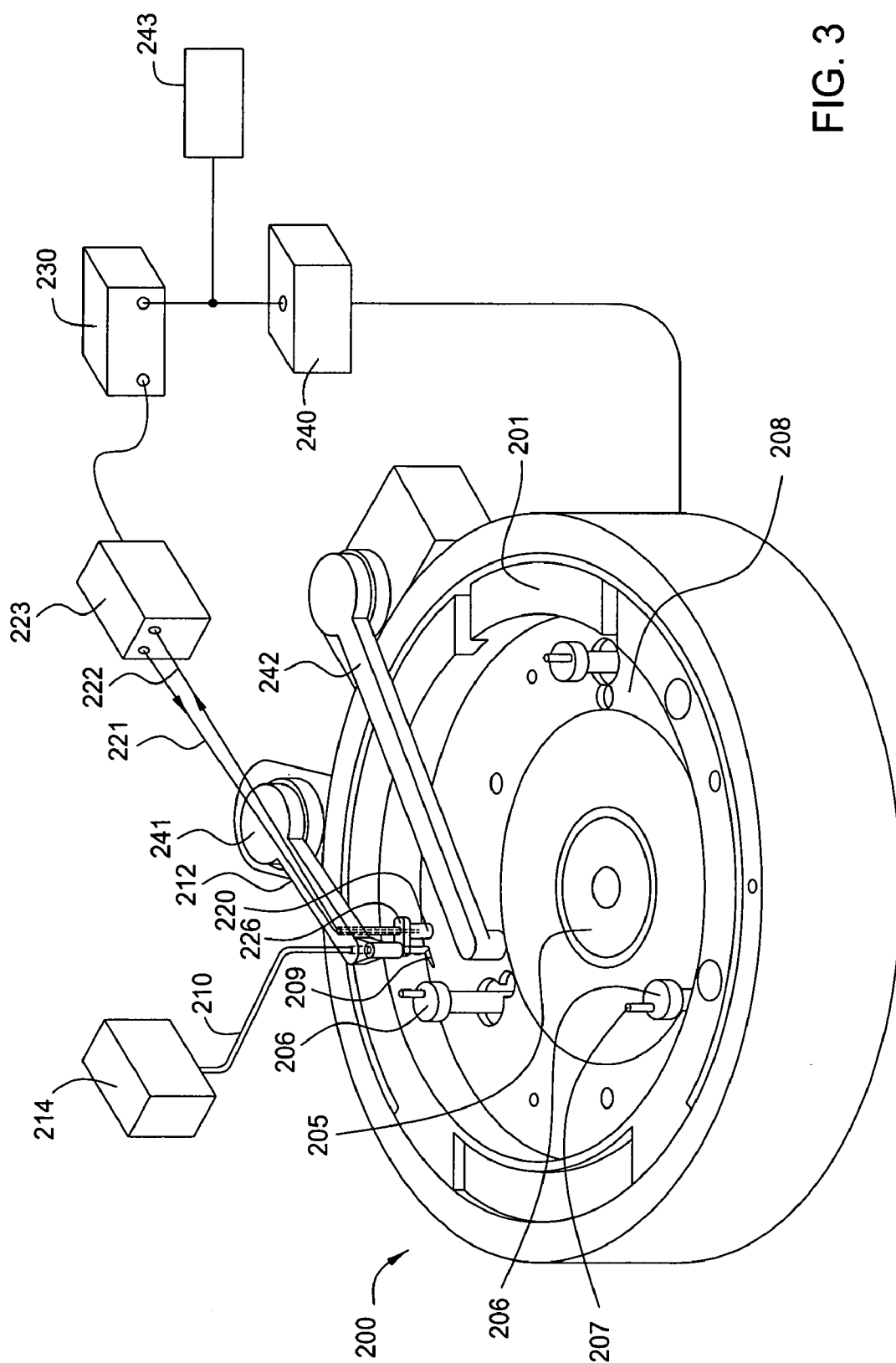
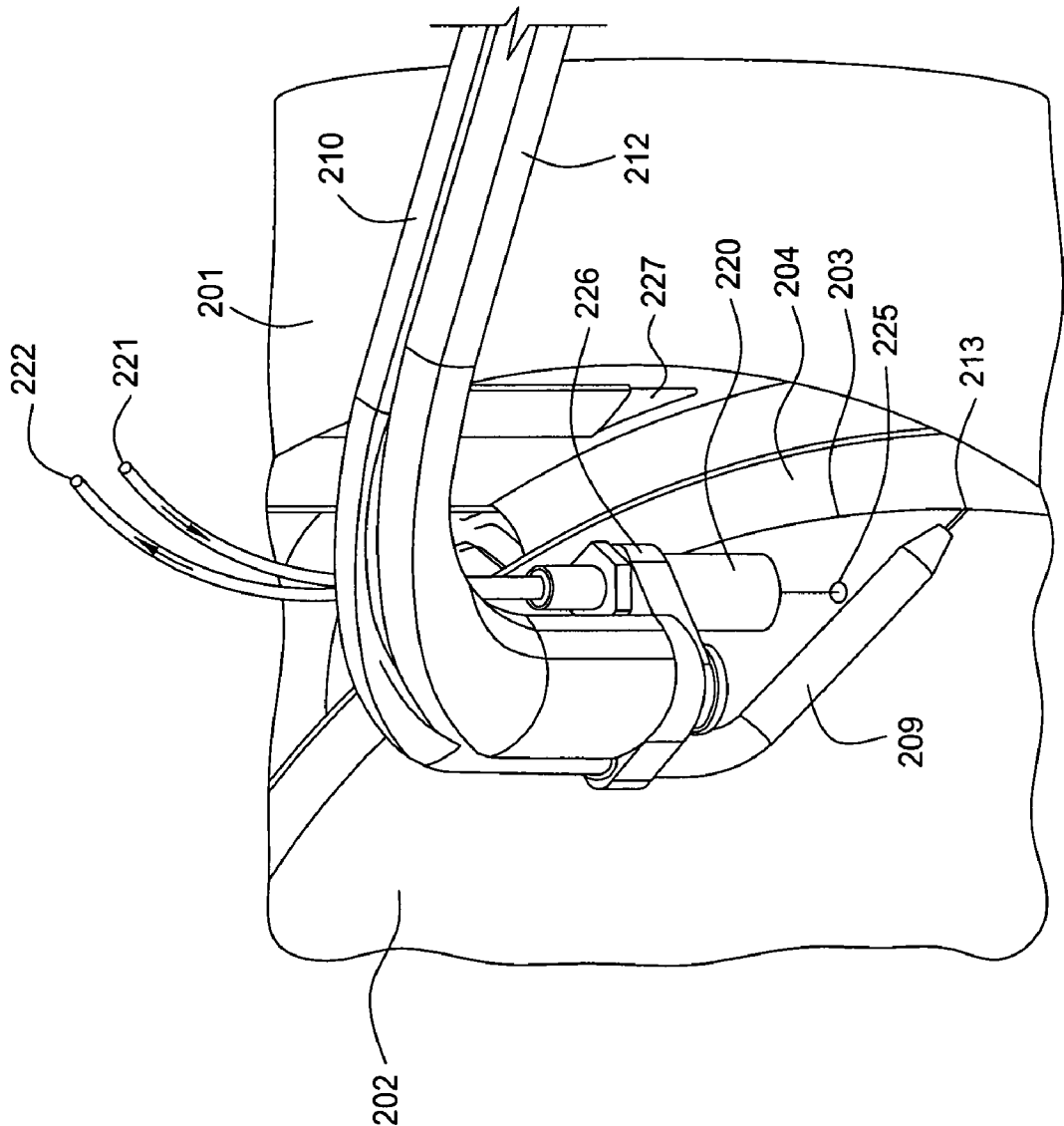


FIG. 4



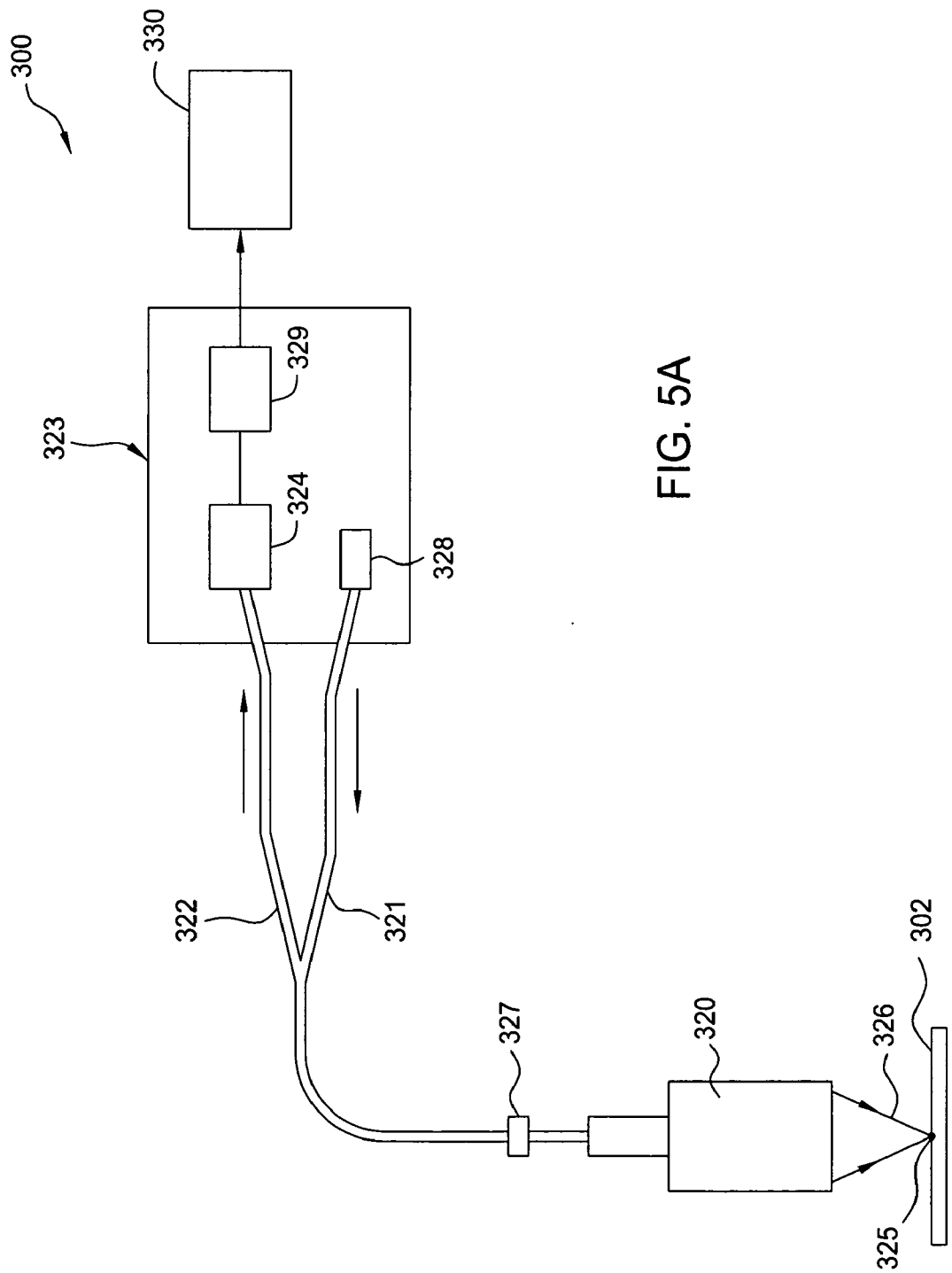


FIG. 5A

FIG. 5B

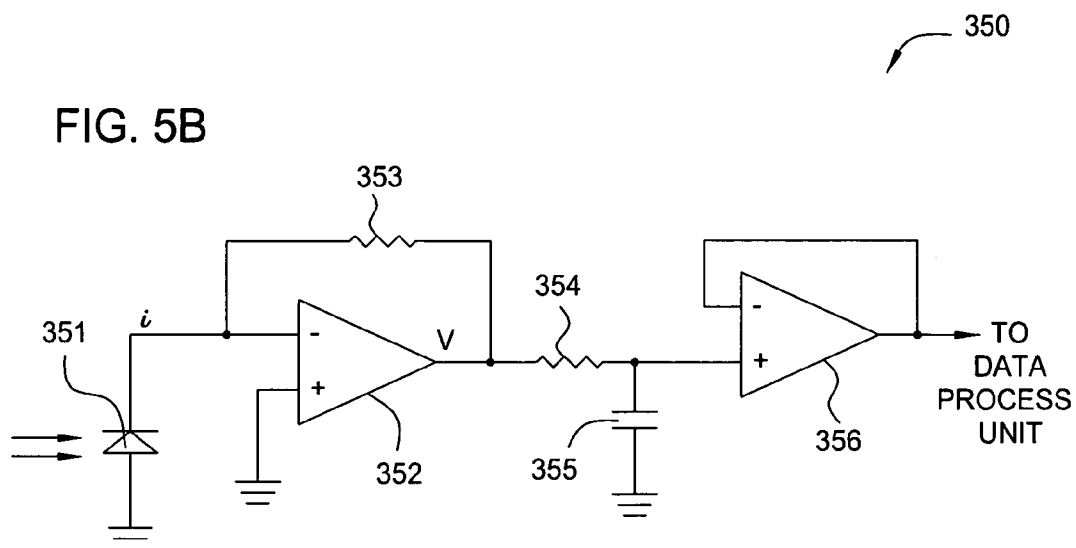
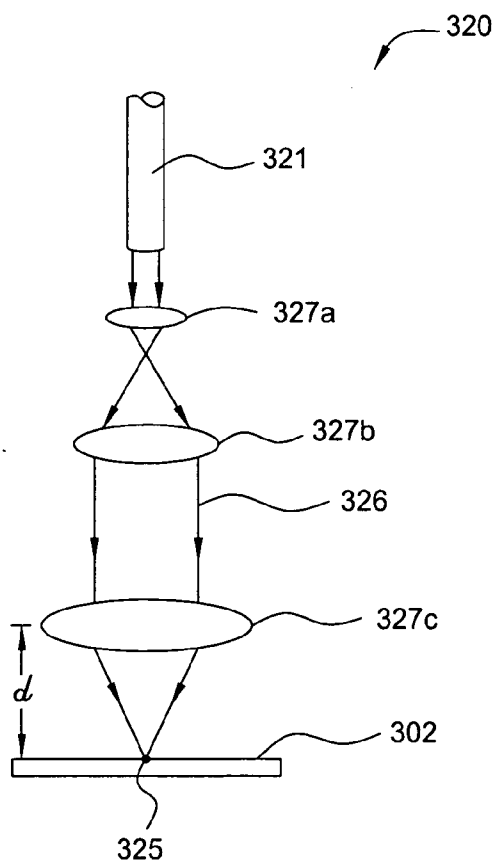


FIG. 5C



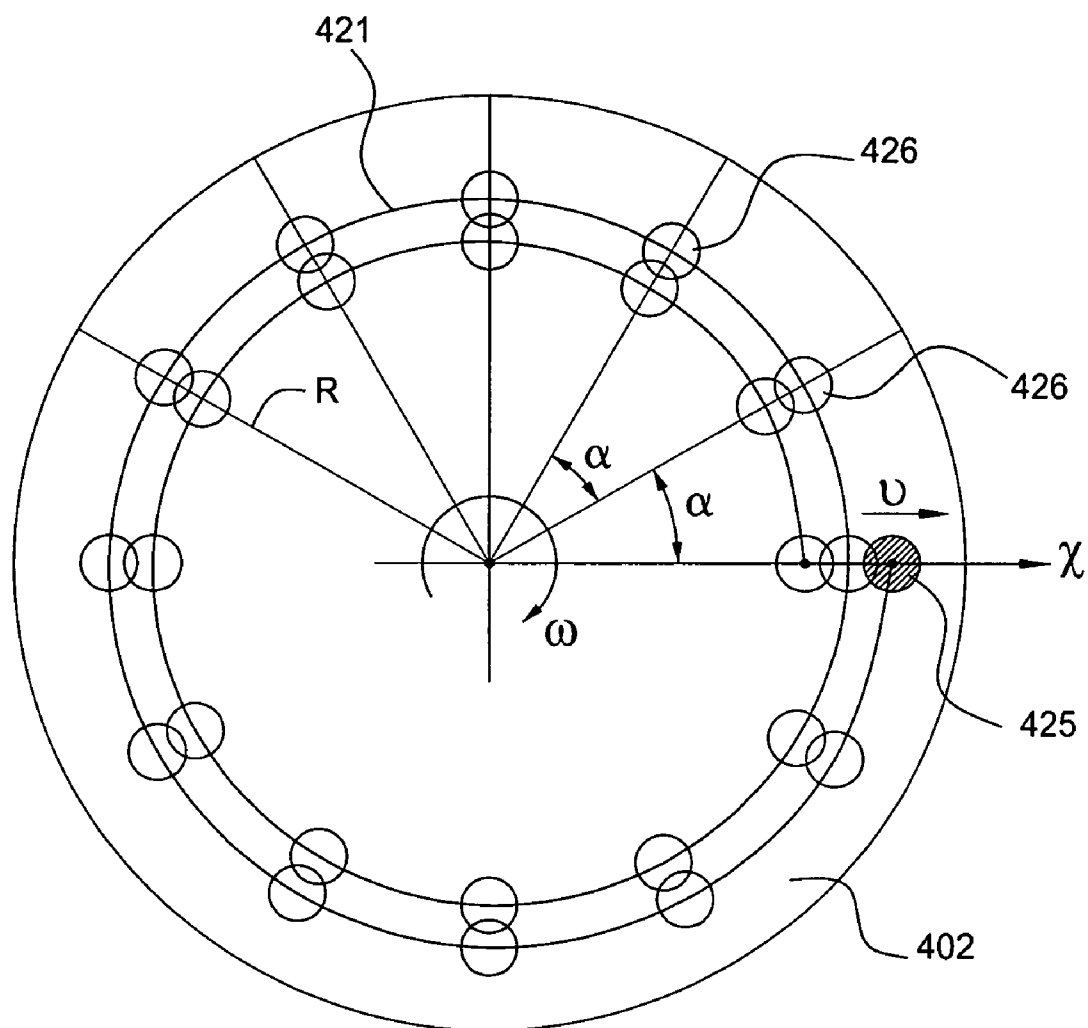


FIG. 6

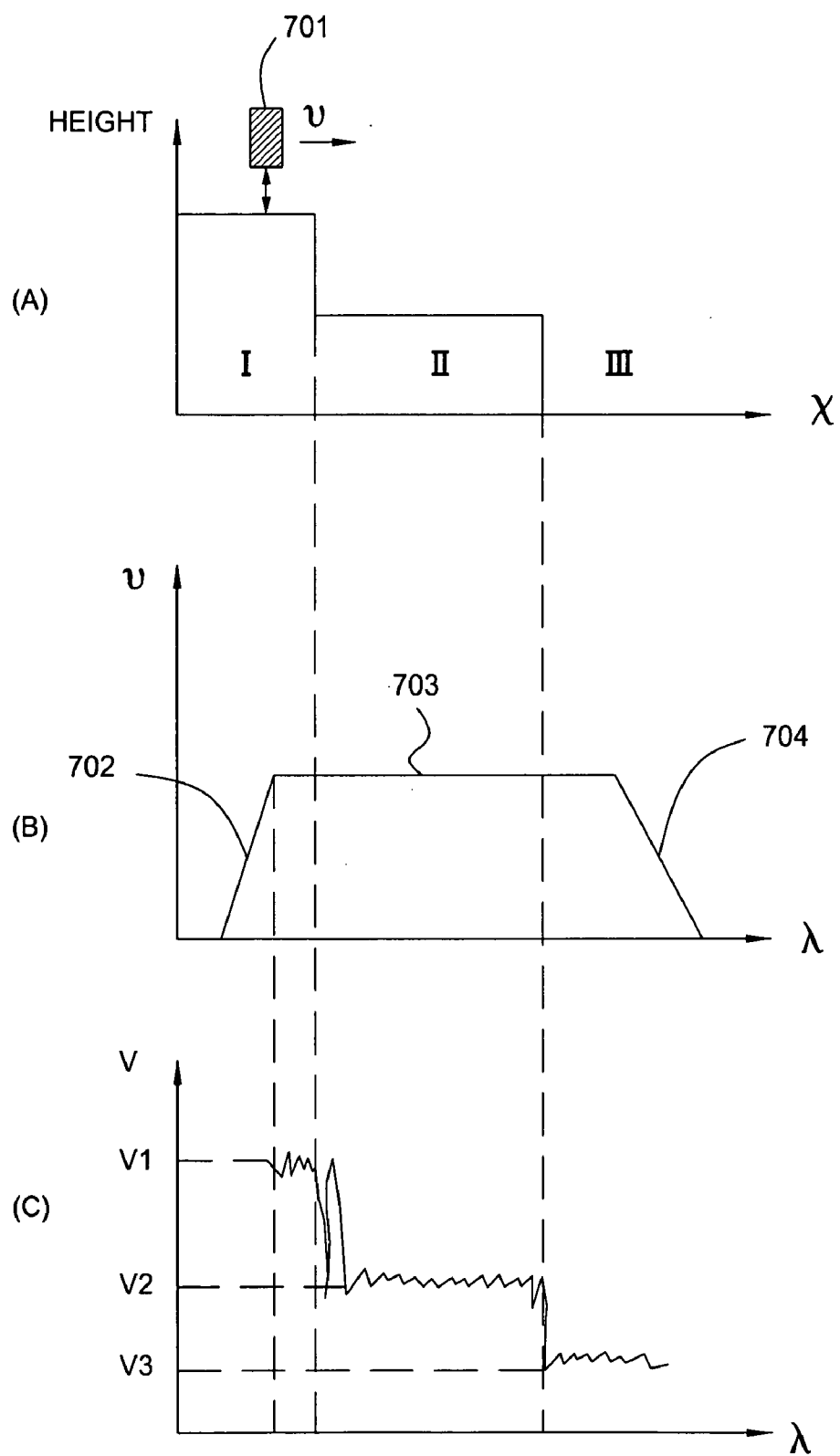


FIG. 7

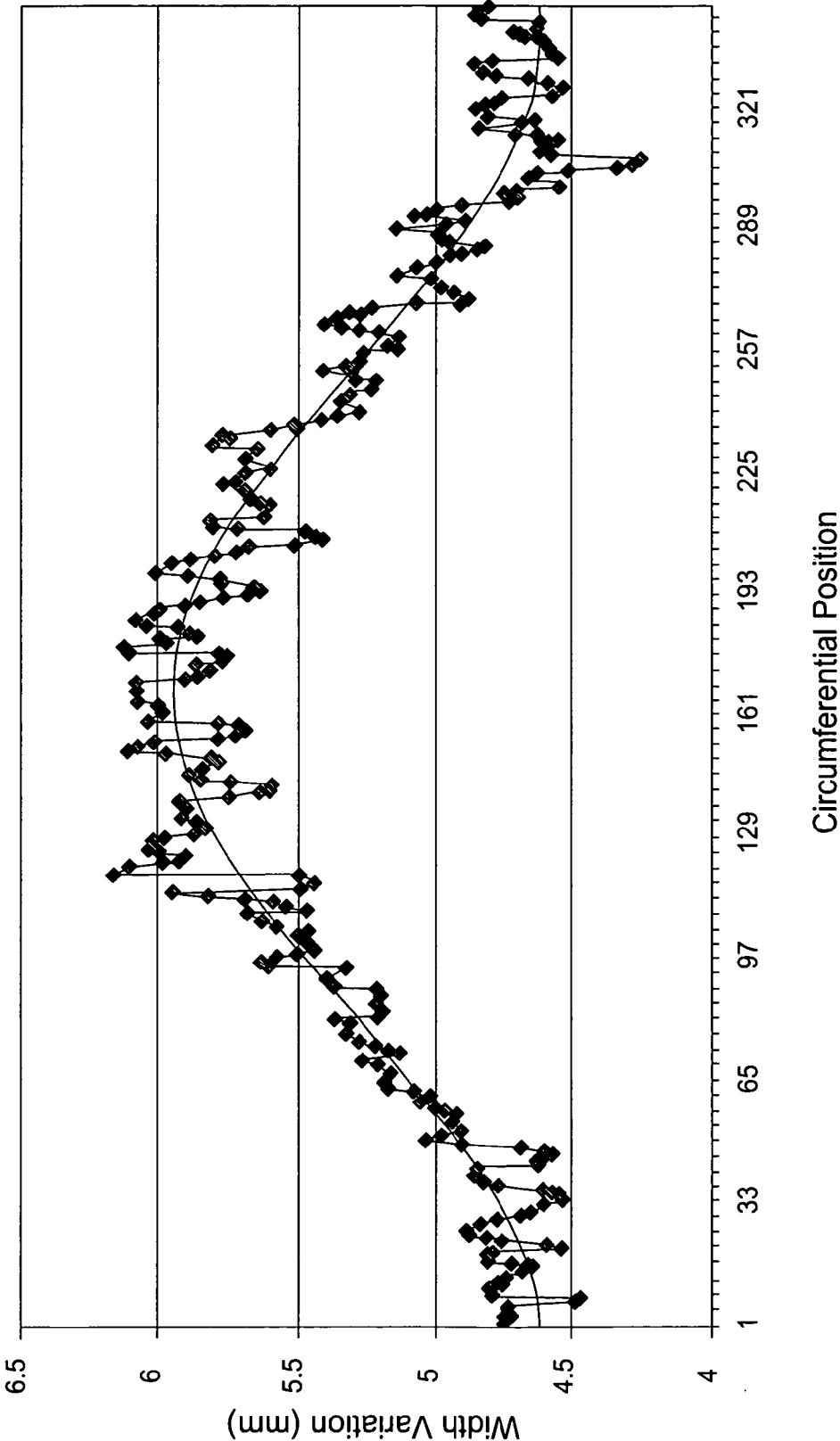


FIG. 8

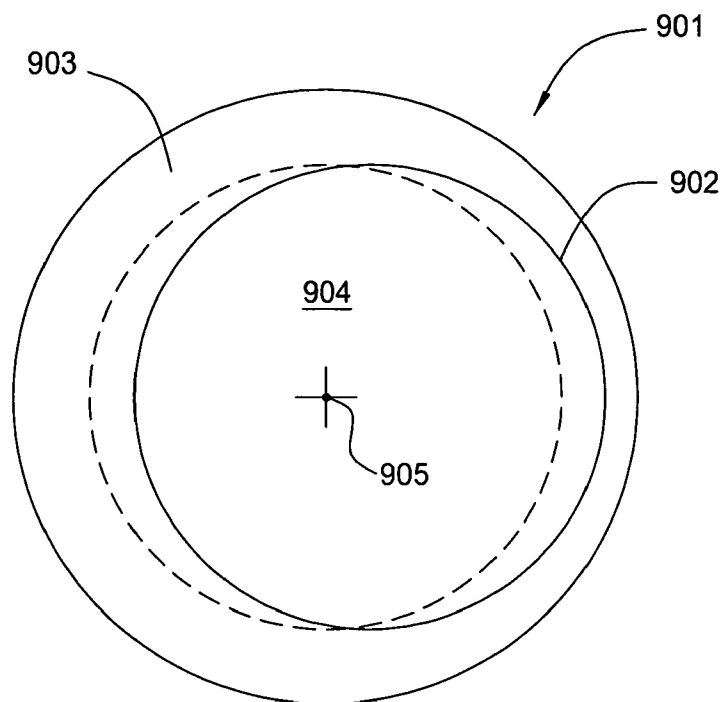


FIG. 9A

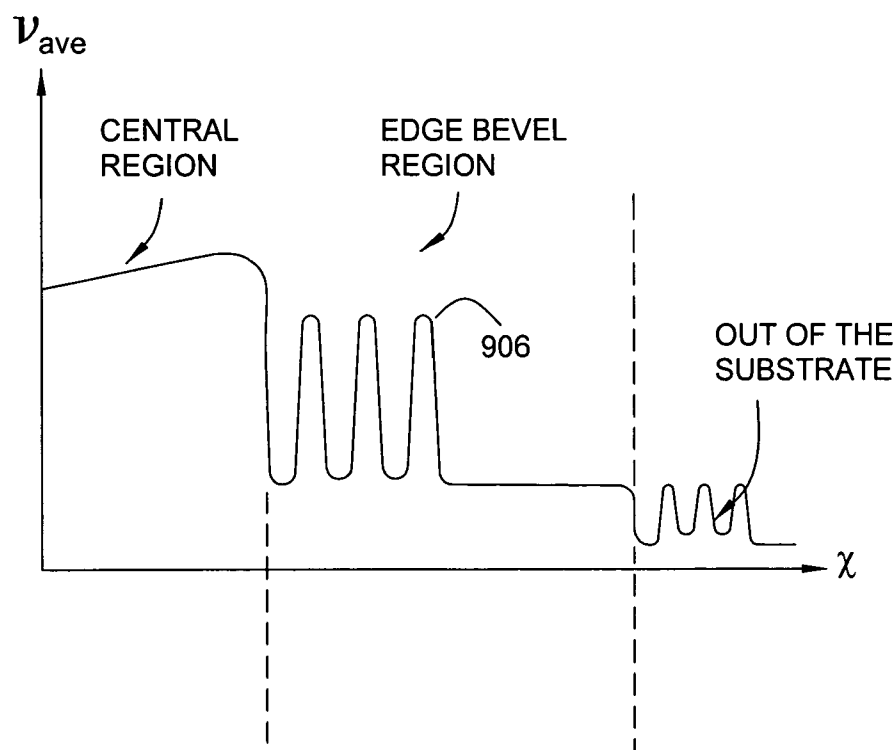


FIG. 9B

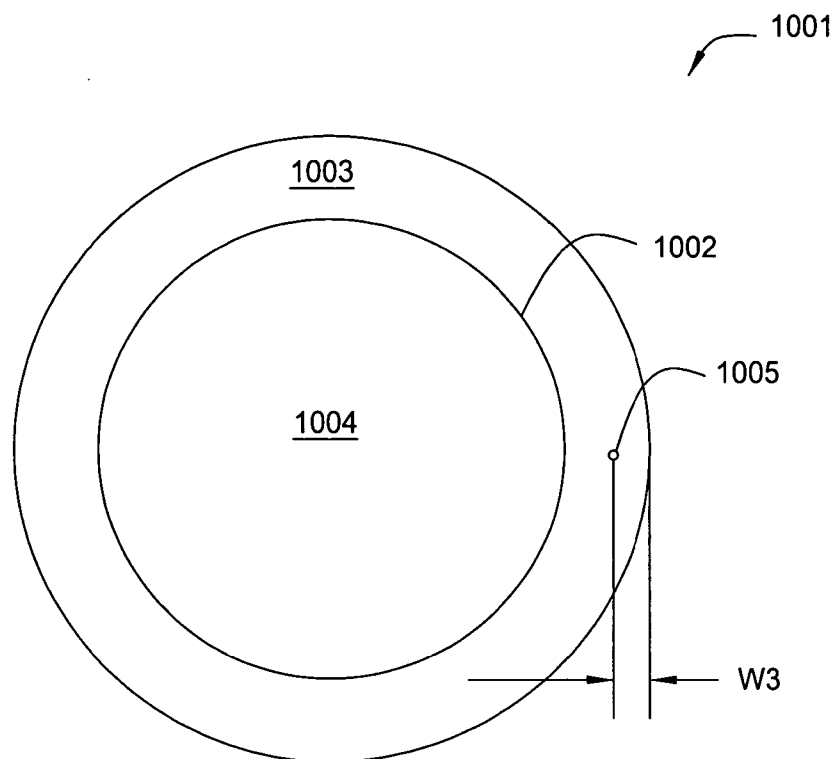


FIG. 10A

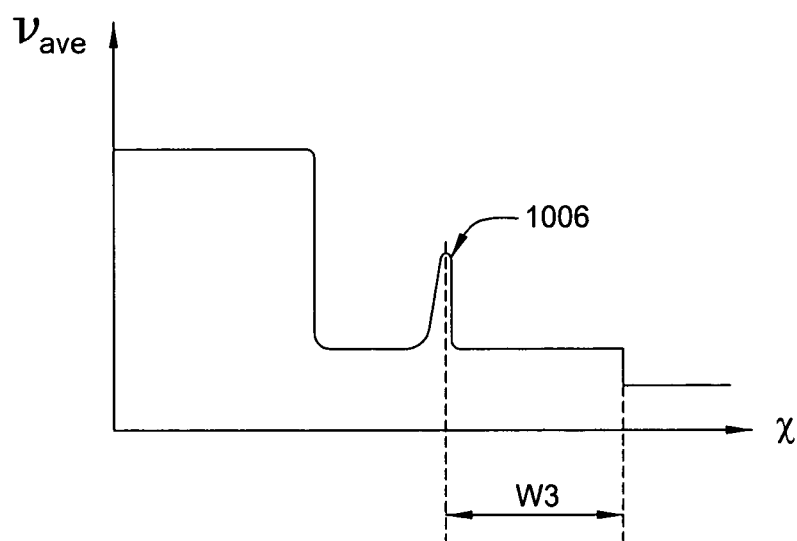


FIG. 10B

COPPER DEPOSITION CHAMBER HAVING INTEGRATED BEVEL CLEAN WITH EDGE BEVEL REMOVAL DETECTION

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] Embodiments of the invention generally relate to an apparatus and method for processing a substrate. More particularly, the present invention relates to detecting and controlling edge bevel removal of a semiconductor substrate.

[0003] 2. Description of the Related Art

[0004] In semiconductor device manufacturing, a multi-layer pattern of conductive, semiconductive, and/or insulating materials is usually generated on a substrate. Multiple deposition processes, such as chemical vapor deposition (CVD), physical vapor deposition (PVD), electrochemical plating (ECP), electroless plating, and/or other deposition processes, are generally conducted in a process series to generate the multilayer pattern.

[0005] During a deposition process, a conductive material is deposited on a front surface of a substrate. However, the conductive material may also deposit on edges, and sides, i.e. bevel, of the substrate where no pattern is located. For a metal layer deposited by a PVD process, the bevel and edge region is usually thin and unevenly deposited; therefore, the metal has poor adhesion and becomes a source of particle contamination. Some materials, e.g. copper, may also migrate from the edge and bevel region to neighboring active regions, especially during an annealing step.

[0006] For a conductive layer deposited by an ECP process, an excess amount of deposition, typically referred to as an edge bead, is formed near the edge region because plating current density is higher near the edge than the remainder of the substrate surface. The edge bead is particularly undesirable. The edge bead may be pulled up and away from the edge of the substrate due to mechanical stress.

[0007] Typically, a planarization process, such as chemical mechanical polishing (CMP) or electro-chemical mechanical polishing (ECMP), is conducted after plating to remove excessive deposit and/or polish the substrate surface between individual layer deposition steps to provide a relatively flat surface for the next deposition. The edge bead is easily torn off from the substrate, damaging the adjacent portion of the substrate. The broken bead may cause further damage to the devices when it becomes loose. To control edge beads, and other unwanted deposition near the edge and bevel region, an edge bevel removal (EBR) process is generally performed after a deposition step.

[0008] An EBR process may be conducted in an EBR system which is configured to dispense an etchant on the perimeter or bevel of a substrate to remove unwanted metal deposited thereon. After an EBR process, a rinse cell is generally used to rinse the surface of the substrate (front and/or back) with a rinsing solution to remove any contaminants and/or residual chemicals therefrom. The rinse cells are generally configured to spin the substrate at a high rate of speed to spin off any remaining rinsing solution droplets adhering to the substrate surface. Once the remaining fluid

droplets are spun off, the substrate is generally clean and dry, and therefore, ready for the next process, e.g. chemical mechanical polishing.

[0009] Generally, there are two primary types of EBR systems which operate to remove the over deposited conductive layers from the substrate: nozzle-type and capillary-type. A nozzle-type EBR system generally rotates a substrate below a nozzle that dispenses a metal removing solution onto the edge and possibly backside of the substrate to remove the edge bead and over-deposited metal layer. Details of an exemplary nozzle-type EBR system may be found in U.S. Pat. No. 6,516,815 granted to Joe Stevens et al, titled "Edge Bead Removal/Spin Rise Dry (EBR/SRD) Module". A capillary-type EBR system generally floats a substrate immediately above a plastic capillary ring configured to direct a metal removing solution dispensing on the back side of the substrate around the bevel area proximate the edge bead.

[0010] Although both types of EBR systems are generally effective in removing the edge bead and over deposited metal layer from the substrate, both systems suffer from inherent disadvantages: for example, the EBR systems have difficulty accurately centering substrates for processing without bowing or even breaking the substrate. Processing an off-centered substrate may cause uneven bevel edge, too thin or too wide bevel edge, incomplete removal, and decrease of valuable surface.

[0011] FIGS. 1 and 2 schematically illustrate a sectional view and a top view of a nozzle-type EBR system **100** of prior art. The EBR system **100** comprises a chamber body **101** defining a processing volume **108**. A substrate support member **105** is disposed in the processing volume **108**. The substrate support member **105** is configured to rotate a substrate **102** about a rotating axis **121**. A lifting assembly **107** having a plurality of lifting pins **106** is disposed in the processing volume **108**. The lifting assembly **107** is configured to move up and down along the rotating axis **121** so that the lifting pins **106** may pick up the substrate **102** from the substrate support member **105** or drop off the substrate **102** onto the substrate support member **105**.

[0012] A fluid dispensing assembly **110** is positioned above the substrate support member **105**. Referring to FIG. 2, the fluid dispensing assembly **110** comprises a dispensing nozzle **109** mounted on a pivoting arm **112** configured to move the dispensing nozzle **109** across the processing volume **108**. The pivoting arm **112** may be driven by a motor **111**. A fluid supply channel **113** is connected to the dispensing nozzle **109** providing a processing fluid to the substrate **102**. The dispensing nozzle **109** is pointed radially outward to prevent the processing fluid from flowing towards central part of the substrate **102**.

[0013] The EBR system **100** is configured to remove deposited metal from an edge region **104** of the substrate **102**. During process, the substrate **102** is first positioned on the lifting pins **106** while the lifting pins **106** are on the up position and the substrate support member **105** is on the down position. The substrate **102** is then picked up by the substrate support member **105** and rotates about the rotating axis **121**. A processing fluid, e.g. an etchant, is dispensed onto the substrate **102** from the dispensing nozzle **109** while the substrate **102** is rotating. The rotating movement spins the processing fluid outwards so that the deposited metal on

the edge region **104** of the substrate **102** is removed and deposited metal on a surface area **103** available for patterning (hereafter available surface area **103**) remains intact. The size of the edge region **104** may be adjusted by pivoting the pivoting arm **112**.

[0014] Ideally, the available surface area **103** is a circle centered at the rotating axis **121** and the edge region **104** is an outer band of the substrate **102**. As feature size decreases, maximization of available surface area **103** on the substrate **102** becomes important. Improper or inaccurate substrate centering can substantially limit the available surface area. Centering the substrate **102** at the rotating axis **121** and positioning the dispensing nozzle **109** in an accurate location are crucial to get an even and accurate edge region **104**. However, EBR systems similar to the EBR system **100** have difficulties centering the substrate to be processed and accurately positioning the dispensing nozzle. FIG. 2 illustrates an example of an off centered edge removal result: the substrate center **122** is offset from the rotating axis **121** and the edge region **104** has a varied width around the substrate **102**. As a result, some of the available surface area may be etched off and some undesired edge bead may remain even after an edge removal process. This may not only decrease the available surface area but also cause damage in latter processing steps. Additionally, misprocessing due to too small or too large an edge region may occur because of drifting in the position of the dispensing nozzle. Furthermore, contaminations or incomplete removal may result particle **120** in the edge region **104** after the edge bevel removal process. The offset, variation of nozzle location, and particles may be detected by running an inspection a separated inspection station. However, separated inspection decreases system efficiency and increases cost of ownership.

[0015] Therefore, there exists a need for an apparatus and method for detecting substrate conditions during an edge bevel removing process.

SUMMARY OF THE INVENTION

[0016] Embodiments of the invention generally provide apparatus and method for detecting and controlling edge bevel removal of a semiconductor substrate.

[0017] One embodiment of the present invention provides an apparatus for inspecting a rotating substrate. The apparatus comprises a substrate support configured to support the rotating substrate on a back side and rotate the substrate about a central axis, and a sensor positioned above the substrate support, the sensor being configured to inspect a front side of the rotating substrate while moving simultaneously radially across the substrate.

[0018] Another embodiment of the present invention provides an apparatus for processing a bevel edge of a rotating substrate. The apparatus comprises a chamber body defining a processing volume, a rotatable substrate support member positioned in the processing volume and configured to support the rotating substrate on a backside, a pivoting arm positioned above the rotatable substrate support member and connected to the chamber body, a fluid dispensing nozzle mounted on the pivoting arm for dispensing a processing fluid a front side of the rotating substrate, and a sensor mounted on the pivoting arm configured to inspect the front side of the rotating substrate simultaneously with processing the rotating substrate.

[0019] Yet another embodiment of the present invention provides a method for inspecting a substrate. The method comprises providing a rotatable substrate support member, providing a sensor pivotably positioned above the substrate support member, positioning the substrate on the substrate support member, and inspecting a front side of the substrate in a spiral motion by pivoting the sensor while rotating the substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] So that the manner in which the above recited features of the present invention can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only 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.

[0021] FIG. 1 illustrates a schematic sectional view of an edge bevel removal system of prior art.

[0022] FIG. 2 illustrates a schematic top view of the edge bevel removal system of FIG. 1.

[0023] FIG. 3 illustrates a schematic perspective view of one embodiment of an edge bevel removal system of the present invention.

[0024] FIG. 4 is an enlarged view of the edge bevel removal system of FIG. 3.

[0025] FIG. 5A illustrates a schematic view of one embodiment of an edge bevel detecting system in accordance with this invention.

[0026] FIG. 5B illustrates a schematic view of one embodiment of a circuit for processing sensor signals in accordance with this invention.

[0027] FIG. 5C illustrates a schematic view of one embodiment of optics in accordance with the present invention.

[0028] FIG. 6 illustrates an exemplary inspecting sequence in accordance with the present invention.

[0029] FIG. 7 illustrates an exemplary edge bevel and inspection result in accordance with the present invention.

[0030] FIG. 8 illustrates an exemplary edge bevel detection result in accordance with the present invention.

[0031] FIG. 9A illustrates a substrate with an eccentric edge bevel in accordance with the present invention.

[0032] FIG. 9B illustrates an exemplary inspecting result of the substrate of FIG. 9A in accordance with the present invention.

[0033] FIG. 10A illustrates a substrate having a particle contamination in the bevel edge area in accordance with the present invention.

[0034] FIG. 10B illustrates an exemplary inspecting result of the substrate of FIG. 10A in accordance with the present invention.

DETAILED DESCRIPTION OF THE
PREFERRED EMBODIMENT

[0035] Embodiments of the invention generally provide an edge bevel removal system capable of monitoring substrates being processed in real-time. The invention is illustratively described below in reference to modification of a Slim-Cell™ system, available from Applied Materials, Inc., Santa Clara, Calif.

[0036] FIG. 3 illustrates an exemplary edge bevel removal system 200 of the present invention. The edge bevel removal system 200 comprises a basin 201 defining a processing volume 208. A substrate chuck 205 is disposed in a central portion of the processing volume 208. The substrate chuck 205 is configured to be rotatable and/or vertically actuatable. In one embodiment, the substrate chuck 205 may be a vacuum chuck having an aperture selectively in fluid communication with a vacuum source.

[0037] The edge bevel removal system 200 may further comprise a substrate centering mechanism configured to adjust a substrate to be processed so that the substrate is substantially centered at a rotating axis of the substrate chuck 205. In one embodiment, the edge bevel removal system 200 comprises three rotatable centering members 206 configured to receive and center the substrate to be processed. The centering members 206 extend upwardly from the bottom of the basin 201 and are positioned radially outward of the substrate chuck 205 in an equal spacing arrangement. A centering pin 207 extending from an off centered position of each centering members 206 is configured to engage the substrate by the edge. When the centering members 206 rotate inwardly, the centering pins 207 move toward the substrate chuck 205 pushing and holding the substrate in a centered position. A detailed description of an exemplary centering assembly may be found in paragraphs 0037-0041 and FIGS. 6, 7A and 7B of U.S. patent application Ser. No. 10/826,492, titled "Integrated Bevel Clean Chamber", filed on Apr. 16, 2004, which is herein incorporated by reference.

[0038] The edge bevel removal system 200 further comprises a chemical arm 212 and a rinsing arm 242. Both arms 212 and 242 are pivotally mounted to a perimeter portion of the edge bevel removal system 200, and include a longitudinally extending arm configured to support at least one fluid dispensing nozzle positioned on a distal end thereof. The chemical arm 212 is configured to facilitate dispensing a processing solution precisely to a radial position of the substrate being processed. The rinsing arm 242 is configured to facilitate dispensing of a rinsing solution onto the substrate. The operation of arms 212 and 242 may be controlled by two separate motorized actuator assemblies, which are configured to precisely position the distal end of the respective arm 212 or 242 over a specified radial position of the substrate being processed via pivotal actuation and/or vertical actuation. In one embodiment, the chemical arm 212 and the rinsing arm 242 may be pivoted by servo motors. A chemical nozzle 209 is mounted on a distal end of the chemical arm 212. In one embodiment, the chemical nozzle 209 is radially pointing outward to prevent the processing solution from flowing towards central part of the substrate. The chemical nozzle 209 is configured to supply the processing solution from a processing solution reservoir 214 via a solution supply channel 210.

[0039] A sensor 220 configured to detect surface conditions of the substrate being processed is mounted on the distal end of the chemical arm 212, which is configured to precisely position the chemical nozzle 209. The sensor 220 is configured to survey the upper surface of the substrate being processed via a pivoting movement carried out by the chemical arm 212 and the rotating movement of the substrate driven by the substrate chuck 205. Mounting the sensor 220 on the chemical arm 212 is economical because the sensor 220 and the chemical nozzle 209 share one high precision positioning mechanism of the chemical arm 212, and no extra movement is required. Additionally, mounting the sensor 220 and the chemical nozzle 209 together also enables simultaneous edge removal and detecting without affecting throughput of the edge bevel removal system 200. The detecting process can be performed when the chemical arm 212 is moving out at a constant speed after finishing the edge removing process.

[0040] In one embodiment, the sensor 220 is an optical sensor which projects a light beam to the upper surface of the substrate and measures the light beam reflected by the upper surface of the substrate. Because different surfaces are different in reflectivity, characteristics of the reflected light beam, such as intensity, can be used to determine the nature of the reflecting surface. For example, a surface of plated copper has a higher reflectivity than a surface of a semiconductor substrate without plated copper, such as an edge area after plated copper has been removed, and the edge area therefore has a higher reflectivity than areas outside the substrate. The reflected light from plated copper surface has a higher intensity than that from an edge area. Therefore, the sensor 220 configured to measure a reflected light beam from a point of a surface can be used to determine if the point being measured is within a plated surface, an edge removal area or outside the substrate.

[0041] The sensor 220 is further connected to a detection box 223 via an input cable 221 and an output cable 222. If the sensor 220 is an optical sensor, the detection box 223 may comprise a light source connected to the input cable 221, a light receiver connected to the output cable 222, and an amplifier circuit. The configuration of the detection box 223 will be described in detail in FIG. 5A. The detection box 223 outputs an electrical signal to a data acquisition box 230 which processes the electrical signal and analyzes surface conditions of the substrate being measured. The data acquisition box 230 may be further connected to the system controller 240 so that the arms 212/242 and the centering members 206 may be calibrated and adjusted according to the measuring results from the sensor 220. In one embodiment, the data acquisition box 230 may be further connected to a system controller 243 to adjust or calibrate robots that transport substrates in and out the edge bevel removal system 200.

[0042] In one aspect, the data acquisition box 230 may include a programming logic controller (PLC). In one aspect, the data acquisition box 230 may take analog signal from the detection box 223 and convert the analog signals to edge bevel removal (EBR) width information, which will be fed into the system controller 240 in the form of 0-5 volt output. The output is linearly proportional to the EBR width. In another aspect, the data acquisition box 230 may provide EBR width and non-concentricity information via RS232 or Ethernet to the system controller 240 or other related con-

trollers. The data acquisition box **230** may further incorporate a hardware or software noise filter to minimize or eliminate possible noise in the incoming signals. In another embodiment, the data acquisition box **230** may have a serial port (USB) to for displaying raw data for diagnostic proposes.

[0043] FIG. 4 illustrates an enlarged view of the edge bevel detecting sensor **220** of FIG. 3. A substrate **202** having an edge bevel area **204** is disposed in the substrate chuck **205** (shown in FIG. 3). A circle **203** indicates a boundary between the edge bevel area **204** and a central region of the substrate **202**. In one embodiment, the sensor **220** is bound to an end of the chemical arm **212** by a bracket **226** made of materials with chemical resistance, for example a VIC-TRES® PEEK™ polymer. In one aspect, the nozzle **209** and the sensor **220** are positioned such that a pinpoint spot **225** inspected by the sensor **220** is radially inside a point **213** sprayed by the chemical nozzle **209**. Thus, during process, when the chemical arm **212** moves the chemical nozzle **209** from radially outward to remove the bevel area **204**, the sensor **220** simultaneously inspects areas already processed. Resolution of measurement from the sensor **220** may be adjusted by varying the rotating rate of the substrate, the speed of the chemical nozzle **209**, and the size of the pinpoint spot. A detailed description will be given in FIGS. 6 and 7. A pocket **227** may be formed on an inner side of the basin **201** to accommodate the sensor **220** and/or the nozzle **209** when the chemical arm **212** moves outside the substrate **202**.

[0044] FIG. 5A illustrates a schematic view of an exemplary optical sensor system **300**, which may be used in the edge bevel removal system **200** of FIG. 3. It should be noted that the optical sensor system **300** may be used independently in an inspection station, or any processing chamber that requires precise positioning of substrate being processed.

[0045] The optical sensor system **300** comprises a light emission source **328** configured to emit an electromagnetic radiation. In one embodiment, the light emission source **328** emits a broad spectrum of radiation across the range of wavelengths from about 200 nm to about 1100 nm. Examples of possible electromagnetic radiation sources might be a tungsten filament lamp, a laser (e.g., yttrium aluminum garnet (YAG), excimer, etc), a laser diode, a xenon lamp, a mercury arc lamp, a metal halide lamp, a carbon arc lamp, a neon lamp, a sulfur lamp, or a combination thereof.

[0046] The light emission source **328** is connected to an optic assembly **320** via an input cable **321**. In one aspect, the input cable **321** is an optic fiber wrapped in a coaxial cable sheath made of polyolefin. The electromagnetic radiation emitted by the light emission source **328** travels through the input cable **321** to the optic assembly **320**. The optic assembly **320** is configured to collimate, focus, and/or direct the electromagnetic radiation from the light emission source **328** and project a signal beam **326** to a processing surface **302** at a pinpoint spot **325**.

[0047] After hitting the processing surface **302**, the signal beam **326** is reflected by the processing surface **302** back to the optic assembly **320**. A detector **324** is connected to an output cable **322**. In one embodiment, the detector **324** is configured to measure the intensity of electromagnetic radiation across one or more wavelengths of the reflected signal

beam **326**. The detector **324** may be selected from the following classes of sensors, for example, a photovoltaic, a photoconductive, a photoconductive-junction, a photoemissive diode, a photomultiplier tube, a thermopile, a bolometer, a pyroelectric sensor or other like detectors.

[0048] The detector **324** converts the reflected signal beam to an electrical signal which is then transferred to an amplifier assembly **329**. The amplifier assembly **329** amplifies the electrical signal from the sensor to a level recognizable by a data processing unit **330** connected thereon. In one embodiment, the amplifier assembly **329** is an analogy amplifier for high precision without introducing A/D error.

[0049] In one embodiment, a filter may be used to dim noises in the electrical signal from the sensor. FIG. 5B schematically illustrates an exemplary amplifier assembly **350** in accordance with the present invention. A diode **351** represents an optical circuit, such as circuit of the detector **324**. The diode **351** generally produces a current that is proportional to the intensity of received signal beam. The diode **351** is electrically connected to a terminal of an amplifier **352** which converts the current from the diode **351** to a voltage with a gain. The amplitude of the gain may be decided by a resistor **353** coupled to the amplifier **352**. In one aspect, the amplifier **352** is coupled to a low-pass filter having a resistor **354** and a capacitor **355**. A voltage follower amplifier **356** may be further connected to the resistor **354** and capacitor **355** for buffering the voltage output.

[0050] FIG. 5C illustrates one embodiment of the optic assembly **320** of the present invention. The optic assembly **320** comprises three lenses **327a**, **327b** and **327c**. The input cable **321** emits the signal beam **326** to the lenses **327a** and **327b** wherein the signal beam **326** is expanded and/or collimated. The lens **327c** then projects the expanded signal beam **326** to the processing surface **302** on the pinpoint spot **325**. In one embodiment, the lenses **327a**, **327b** and **327c** are acrylic lenses. In one configuration, the lenses **327a**, **327b** and **327c** may have diameter of about 3 millimeter and the distance *d* between the lens **327c** to the processing surface **302** is about 7.5 millimeter. In another embodiment, the lenses **327a**, **327b** and **327c** are gradient index lenses (GRIN). The size of the pinpoint spot **325** may be adjusted by changing the distance *d*.

[0051] An edge bevel processing system of the present invention, for example the edge bevel removal system **200** of FIG. 3, may perform edge bevel removal and inspecting the edge bevel simultaneously. During process, a substrate is centered in a substrate support member and spun by the substrate support member. A chemical arm carrying a fluid dispensing nozzle and a sensor moves outwardly across the substrate. In one embodiment, the fluid dispensing nozzle and the sensor are positioned such that the fluid dispensing nozzle focuses at a point radially outward in respect to a focus point of the sensor. When the focus point of the fluid dispensing nozzle reaches an inner edge of an edge bevel area, a processing fluid is dispensed onto the substrate. During processing, the chemical arm is stationary and moves outward when the process is complete. As the chemical arm moves outward, the focus point of the sensor reaches the bevel area and the bevel area may be measured. Signals from the sensor may be sampled and processed so that characteristics of the bevel edge become known as soon as the edge bevel process is finished.

[0052] FIG. 6 illustrates an exemplary inspecting process. A substrate 402 rotates at a speed ω . A sensor (not shown) moves at speed v along axis x thus the pinpoint spot 425 of the sensor also moves at speed v along axis x . It should be noted that the sensor actually moves in a pivoting motion. The movement of the sensor may be considered linear near the edge bevel area because the pivoting radius of the sensor is relative large compared to the width of a bevel edge, which is generally less than about 5 millimeter. The measurement inaccuracy due to the a slight nonlinearity of the arm movement can be corrected by incorporating a correction factor in final data processing.

[0053] A spiral curve 421 illustrates the trajectory of the pinpoint spot 425 on the substrate due to the linear movement of the sensor and the spinning movement of the substrate. In one embodiment, both the rotating speed ω and the linear speed v are constant. The sensor signal may be sampled at a period dt . Spots 426 represents locations on the substrate 402 where the sensor signal are sampled. Spots 426 sampled immediately next to each other have an angle of α ($\alpha = \omega * dt$). Adjusting dt and ω appropriately, the spots 426 may distribute in groups along a plurality of radii R that are α degrees away from one another. In one aspect, properties of the substrate 402 along a radius may be measured by analyzing sensor signals from spots 426 along the radius. The properties may include width of edge bevel area along the radius, surface conditions along the radius, and contaminations. In one embodiment, the spot 426 may overlap with its immediate neighboring spot 426 along the same radius for a precise measurement. In one aspect, the spots 426 may be circles having a diameter of about 0.15 mm and neighboring spots 426 may overlap by about 0.05 mm along the diameter, which is about 30%. The overlapping may be realized by adjusting linear speed v , and/or spot size, and/or rotation speed ω .

[0054] FIG. 7 illustrates an exemplary edge bevel and inspection result along one radius. The horizontal axes in charts (a), (b) and (c) illustrate distance from center of the substrate. Chart (a) of FIG. 7 illustrates a sectional view of a substrate along one radius. The vertical axis of chart (a) illustrates the height of the substrate. Region I represents the center area of the substrate. Region II represents the edge bevel area where a layer of material has been removed. Region III represents outside the substrate. During an inspecting process, a sensor 701 positioned above the substrate moving from above Region I to above Region III at speed v , projecting a signal beam to the substrate surface and sensing a reflected signal beam. Chart (b) of FIG. 7 illustrates the speed v of the sensor 701 from Region I to Region III. Chart (b) shows that the sensor 701 rapidly accelerates along line 702 to a constant speed shown in line 703 within Region I. The sensor 701 passes the rest of the Region I, Region II and part of Region III at the constant speed, then stops in Region III. Chart (c) illustrates a measuring result along one radius of the substrate. Due to difference in reflectivity of Regions I, II and III, the measured signal values from Regions I, II and III are $V1$, $V2$ and $V3$ respectively. Thus, width of the bevel edge, Region II, may be determined from measured signal values from chart (c).

[0055] FIG. 8 illustrates an exemplary edge bevel detection result along a circumference of a substrate. The horizontal axis represents circumferential positions of a substrate. The vertical axis represents width of the bevel edge of

the substrate. The exemplary result in FIG. 8 shows a varied width of the bevel edge along the circumference of the substrate. The degree of width variation may be measured with eccentricity, which may be related to a measured width in the following form:

$$w_{\text{measured}}(x) = E \sin(x + \theta) + w_{\text{average}} \quad (\text{Equation 1})$$

where x denotes a circumferential position, w_{measured} denotes measured width, w_{average} is average value of all the measured width, θ is a phase shift, and E is the amplitude of the eccentricity. In one aspect, after a substrate is measured, the measured width w_{measured} for every circumferential position may be calculated from the measurement. The average width w_{average} can then be easily calculated from the measured width w_{measured} . Then amplitude of eccentricity E may be calculated by fitting w_{average} and w_{measured} into Equation 1.

[0056] FIG. 9A illustrates a substrate 901 having an eccentric edge bevel region 903 in respect to a center point 905 of the substrate 901. Curve 902 is the boundary between a central region 904 and the edge bevel region 903. In one embodiment, the eccentricity of edge bevel region 903 may be detected by averaging measurements of all the circumferential positions. FIG. 9B illustrates an exemplary inspecting result of the substrate of FIG. 9A. The horizontal axis of FIG. 9B illustrates a distance to the center point 905 of the substrate 901 and the vertical axis indicates average measured signal values. FIG. 9B is similar to chart (c) of FIG. 7, only with averaged values. A peak 906 in the edge bevel region indicates an eccentricity of the bevel edge region.

[0057] FIGS. 10A-B illustrates another exemplary substrate 1001 and its measurement. The substrate 1001 has a bevel edge region 1003 and a central region 1004. Curve 1002 indicates the boundary between the bevel edge region 1003 and the central region 1004. A contamination 1005, such as a metal spot due to an incomplete bevel edge removal, is located in the bevel edge region 1003. The distance between the contamination 1005 and an edge of the substrate 1001 is $w3$. Similar to FIG. 9B, FIG. 10B illustrates an average measurement along all the circumferential positions. A small peak 1006 indicates the existence and the distance of the contamination 1005 from the edge of the substrate 1001.

[0058] As discussed, the apparatus and method of the present invention provide build-in quality control in a bevel edge removing system. Measuring an edge region of a substrate being processed can be performed simultaneously as bevel edge removal, thus shortening inspection time. Misprocessing of a system, for example bevel edge too wide or too thin, may be detected immediately, thus minimizing damage. Contaminations and incomplete removal may be detected while the substrate is still in the chamber, providing opportunities to fix problems in-situ. Further, eccentricity of the substrate and/or bevel edge region can be measured, thus, providing means to calibrate the fluid dispensing nozzles, centering assemblies, and transferring robots.

[0059] Although, the above discussion is focused on processing a semiconductor substrate, the present invention may also be used in processing various substrates, such as a glass substrate for a liquid crystal display, a plasma display panel, or a ceramic substrate for magnetic discs.

[0060] While the foregoing is directed to embodiments of the present invention, other and further embodiments of the

invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

1. An apparatus for inspecting a rotating substrate, comprising:

a substrate support configured to support the substrate on a back side and rotate the substrate about a central axis; and

a sensor positioned above the substrate support, the sensor being configured to inspect a front side of the rotating substrate while moving simultaneously radially across the rotating substrate.

2. The apparatus of claim 1, further comprising a data processing unit configured to process signals from the sensor and determine characteristics of the rotating substrate.

3. The apparatus of claim 2, wherein the data processing unit is configured to determine an eccentricity of the rotating substrate relative to the central axis.

4. The apparatus of claim 2, wherein the data processing unit is configured to determine surface conditions of the rotating substrate.

5. The apparatus of claim 2, wherein the sensor is mounted on a nozzle for dispensing an etchant to clean a bevel edge of the rotating substrate.

6. The apparatus of claim 5, wherein the data processing unit is configured to determine width of the bevel edge.

7. The apparatus of claim 1, wherein the sensor is an optical sensor configured to measure a reflected light beam from the front side of the rotating substrate.

8. The apparatus of claim 7, wherein the optical sensor is operably connected to an amplifier and a data acquisition unit.

9. An apparatus for processing a bevel edge of a rotating substrate, comprising:

a chamber body defining a processing volume;

a rotatable substrate support member positioned in the processing volume and configured to support the rotating substrate on a backside;

a pivoting arm positioned above the rotatable substrate support member and connected to the chamber body;

a fluid dispensing nozzle mounted on the pivoting arm for dispensing a processing fluid a front side of the rotating substrate; and

a sensor mounted on the pivoting arm configured to inspect the front side of the rotating substrate simultaneously with processing the rotating substrate.

10. The apparatus of claim 9, further comprising a control unit configured to adjust at least one of the rotatable substrate support member, the pivoting arm, and the fluid dispensing nozzle according to an inspection result from the sensor.

11. The apparatus of claim 9, wherein the pivoting arm is coupled to a servo motor configured to move the pivoting arm substantially radially across the processing volume.

12. The apparatus of claim 9, wherein the sensor is an optical sensor.

13. The apparatus of claim 12, wherein the optical sensor comprises lenses configured for expanding and projecting light beams to the front side of the rotating substrate.

14. The apparatus of claim 12, wherein the sensor is coupled to an analog amplifier and a data acquisition system.

15. The apparatus of claim 9, further comprising a data processing unit coupled to the sensor and configured to calculate characteristics of the bevel edge inspected by the sensor.

16. The apparatus of claim 15, wherein the characteristics comprise at least one of a width of the bevel edge, eccentricity of the bevel edge, and location of contaminations on the bevel edge.

17. The apparatus of claim 15, wherein the data processing unit is further configured to measure eccentricity of the rotating substrate relative to a rotating axis of the rotatable substrate support member.

18. A method for inspecting a substrate, comprising:

providing a rotatable substrate support member;

providing a sensor pivotably positioned above the substrate support member;

positioning the substrate on the substrate support member; and

inspecting a front side of the substrate in a spiral motion by pivoting the sensor while rotating the substrate.

19. The method of claim 18, wherein the inspecting the front side of the substrate comprises:

projecting an optical beam onto the front side of the substrate; and

measuring a reflected optical beam from the front side of the substrate.

20. The method of claim 19, wherein the inspecting the front side of the substrate further comprises determining characteristics of the substrate from measurement of the reflected optical beam.

21. The method of claim 19, wherein projecting the optical beam comprises projecting a beam spot on the front side of the substrate, wherein at least one of a rotating rate, pivoting rate, and size of the beam spot is adjusted such that along a given radius, neighboring beam spots overlap one another.

22. The method of claim 21, wherein overlapping ratio is about 30%.

23. The method of claim 18, wherein the pivoting is performed such that the sensor moves radially outwardly and or inwardly in a constant speed.

24. The method of claim 18, further comprising calculating width of a bevel edge along a periphery of the substrate.

25. The method of claim 18, further comprising:

providing a chemical nozzle configured to dispensing a processing fluid to the front side to the substrate, wherein the sensor is mounted on a side of the chemical nozzle; and

processing the substrate while inspecting simultaneously.

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