Apparatus and methods are provided to polish a notch of a substrate. The invention includes a polishing head adapted to apply a polishing tape against the notch of the substrate, including: a plunger; and an actuator, wherein the actuator is adapted to move the plunger with respect to the polishing tape. Numerous other aspects are provided.
FIG. 3

[Diagram of mechanical or electrical equipment, labeled with various components such as 300, 308, 310, 312, 316, etc.]
900 Secure Substrate on Support

902 Align Substrate Notch with Polishing Head

904 Press Polishing Tape Against Notch

906 Advance Polishing Tape

908 Rotate Polishing Head About Substrate Notch

FIG. 9
METHODS AND APPARATUS FOR POLISHING A NOTCH OF A SUBSTRATE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application is related to the following commonly-assigned, co-pending U.S. Patent Applications, each of which is hereby incorporated herein by reference in its entirety for all purposes:


[0004] U.S. patent application Ser. No. _______, filed Oct. 24, 2008, entitled “METHODS AND APPARATUS FOR POLISHING A NOTCH OF A SUBSTRATE WITH A MANDREL” (Attorney Docket No. 10672/L); and


FIELD OF THE INVENTION

[0006] The present invention relates generally to substrate processing, and more particularly to methods and apparatus for cleaning a notch in an edge of a substrate.

BACKGROUND OF THE INVENTION

[0007] Conventional systems, which contact a notch in the edge of a substrate with an abrasive tape to clean the notch, may not be able to contact all parts of the notch with the abrasive tape. As a result, these conventional systems may not be able to clean or polish all parts of the notch. Accordingly, effective methods and apparatus for cleaning or polishing all parts of notches in the edges of substrates are desired.

SUMMARY OF THE INVENTION

[0008] In some aspects of the invention an apparatus is provided for polishing a notch of a substrate. The apparatus includes a polishing head adapted to apply a polishing tape against the notches of the substrate. The polishing head includes a plunger, and an actuator, wherein the actuator is adapted to move the plunger with respect to the polishing tape.

[0009] In other aspects of the invention, a system is provided for polishing a notch of a substrate. The system includes a substrate support adapted to rotate a substrate; and a polishing head adapted to apply a polishing tape against the notch of the substrate. The polishing head includes a plunger; and an actuator, wherein the actuator is adapted to press the plunger into the polishing tape and thereby press the polishing tape against the notches. The system also includes a controller adapted to operate the rotation of the substrate and the actuator.

[0010] In yet other aspects of the invention, a method is provided for polishing a notch of a substrate. The method includes (1) securing a substrate on a support; (2) aligning a substrate notch with a polishing head including a plunger; (3) pressing a polishing tape against a notch with the plunger; and (4) advancing the polishing tape as the polishing tape is pressed against the notch.

[0011] Other features and aspects of the present invention will become more fully apparent from the following detailed description, the appended claims and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIG. 1 is a schematic illustration of a cross-section of a portion of a substrate.

[0013] FIG. 2 is a schematic plan view of an embodiment of a system for polishing parts of a substrate, including major surfaces, edge, bevel, and notch.

[0014] FIG. 3 is a schematic perspective view of an embodiment of a polishing apparatus for polishing a substrate notch.

[0015] FIG. 4 is a schematic illustration of part of a substrate, including a substrate notch.

[0016] FIG. 5 is a schematic perspective view of a portion of an embodiment of the notch polishing apparatus of FIG. 3.

[0017] FIG. 6 is a plan view of an example of polishing tape being pressed into a substrate notch by a plunger in accordance with some embodiments of the present invention.

[0018] FIG. 7 is a plan view of an example of polishing tape being pressed into a substrate notch by an angled plunger in accordance with some embodiments of the present invention.

[0019] FIG. 8 is a schematic perspective view of another embodiment of a polishing apparatus for polishing a substrate notch.

[0020] FIG. 9 is a flow chart of a method for polishing a substrate notch in accordance with the present invention.

DETAILED DESCRIPTION

[0021] Substrates used in semiconductor processing often have films and/or surface defects which it is helpful to remove prior to subsequent processing steps. These films and defects may occur on the edge of a substrate, including notches formed thereon.

[0022] In some embodiments, the present invention provides apparatus and methods that effectively adapt to various shapes of notches found in different substrates, ensure good contact of a polishing or abrasive film or tape with all sections of a substrate notch region, and remove thin films and surface defects at a substrate notch. In one or more embodiments, a polishing plunger may be provided. The polishing plunger may be adapted to press a moving polishing tape against the substrate notch. The polishing plunger may substantially conform to the shape of the substrate notch, such that the polishing tape contacts all portions of the notch.

[0023] Turning to FIG. 1, a substrate 100 may include two major surfaces 102, 102' and an edge 104. Each major surface 102, 102' of the substrate 100 may include a device region 106, 106' and an exclusion region 108, 108'. (Typically however, only one of the two major surfaces 102, 102' will include a device region and an exclusion region.) The exclusion regions 108, 108' may serve as buffers between the device regions 106, 106' and the edge 104. The edge 104 of the substrate 100 may include an outer edge 110 and bevels 112, 114. The bevels 112, 114 may be located between the outer edge 110 and the exclusion regions 108, 108' of the two major surfaces 102, 102'. A notch 116 may be located in the outer edge 110 of the substrate 100. In some embodiments, the
present invention may be adapted for use with a system adapted to clean and/or polish the outer edge 110 and at least one bevel 112, 114 of the substrate 100 without affecting the device regions 106, 108. In some embodiments, all or part of the exclusion regions 108, 109 may be cleaned or polished as well.

[0024] FIG. 2 is a schematic plan view of an embodiment of a system 200 for polishing parts of the substrate 100, including the major surfaces 102, 104, the edge 104, and the notch 116. The system 200 includes three polishing apparatuses 202, each including a polishing head 204. However, any number and type of apparatus 202/heads 204 may be used in any practicable combination. In addition, in such multi-head embodiments, each head 204 may use a differently configured or type of a polishing tape (e.g., different grits, materials, tensions, pressures, etc.) to contact and polish the substrate edge 104 and/or notch 116. Any number of heads 204 may be used concurrently, individually, and/or in any sequence. The heads 204 may be disposed in different positions and/or in different orientations (e.g., aligned with the substrate edge 104 and/or notch 116, normal to the substrate edge 104 and/or notch 116, angled relative to the substrate edge 104 and/or notch 116, etc.) to allow polishing tape, pushed by a plunger in some embodiments (FIG. 3), to polish different portions of the substrate edge 104 and/or notch 116.

[0025] In some embodiments, one or more of the heads 204 may be adapted to OSC or moved (e.g., pivoted or angularly translated) about a tangential axis of the substrate 102 and/or circumferentially relative to the substrate 102, around or along the substrate edge 104 and/or notch 116 so as to polish different portions of the substrate edge 104 and/or notch 116. In some embodiments, one or more of the heads 204 may be adapted to continuously or intermittently oscillate between the various positions. Alternatively, one or more of the heads 204 may be fixed and/or only adjusted while the substrate 102 is not being rotated. In yet other embodiments, the substrate 102 may be held fixed while one or more of the heads 204 oscillate (as described above) as well as rotate circumferentially around the substrate 102. This movement may be under the direction of a programmed or user operated controller 206, described below. Different heads 204 may be used for different substrates 100 or different types of substrates 100.

[0026] As described above, the system 200 may further include the controller 206, (e.g., a programmed computer, a programmed processor, a microcontroller, a gate array, a logic circuit, an embedded real time processor, etc.), which may control the driver(s) used to rotate the substrate 100 and/or the actuator(s) used to push a polishing plunger(s) (FIG. 3) against the substrate edge 104 and/or notch 116. Note that the controller 206 may be coupled (e.g., electrically, mechanically, pneumatically, hydraulically, etc.) to each of a plurality of actuators. Likewise, the controller 206 may be adapted to receive feedback signals from one or more drivers and/or actuators, that indicate the amount of energy being exerted to rotate the substrate 100 (e.g., rotate a chuck holding the substrate 100) and/or actuate the actuator(s) to push the polishing plunger (FIG. 3) against the substrate notch 116. As described further below, these feedback signals may be employed to determine when a particular layer of film has been removed from the edge 104 and/or notch 116 of the substrate 100 and whether a sufficient amount of substrate polishing has occurred.

[0027] As mentioned above, substrate polishing may be performed using one or more polishing apparatuses 202. In one or more embodiments, a plurality of polishing apparatuses 202 may be employed, in which each polishing apparatus 202 may have similar or different characteristics and/or mechanisms. In the latter case, particular polishing apparatuses 202 may be employed for specific operations. For example, one or more polishing apparatuses 202 may be adapted to perform relatively rough polishing and/or adjustments while another one or more polishing apparatus 202 may be adapted to perform relatively fine polishing and/or adjustments. Polishing apparatuses 202 may be used in sequence so that, for example, a rough polishing procedure may be performed initially and a fine polishing procedure may be employed subsequently as needed or according to a polishing recipe. The plurality of polishing apparatuses 202 may be located in a single chamber or module, as shown herein, or alternatively, one or more polishing apparatuses 202 may be located in separate chambers or modules. Where multiple chambers are employed, a robot or another type of transfer mechanism may be employed to move substrates 100 between the chambers so that polishing apparatuses 202 in the separate chambers may be used in series or otherwise.

[0028] Substrate (edge/notch) polishing may be performed using one or more polishing apparatuses 202. In one or more embodiments, a plurality of polishing apparatuses 202 may be employed, in which each polishing apparatus 202 may have similar or different characteristics and/or mechanisms. In the latter case, particular polishing apparatuses 202 may be employed for specific operations. For example, one or more of a plurality of polishing apparatuses 202 may be adapted to perform relatively rough polishing and/or adjustments while another one or more of the plurality of polishing apparatus 202 may be adapted to perform relatively fine polishing and/or adjustments. Polishing apparatuses 202 may be used in sequence so that, for example, a rough polishing procedure may be performed initially and a fine polishing procedure may be employed subsequently to make adjustments to a relatively rough polish as needed or according to a polishing recipe. The plurality of polishing apparatuses 202 may be located in a single chamber or module, as shown herein, or alternatively, one or more polishing apparatuses 202 may be located in separate chambers or modules. Where multiple chambers are employed, a robot or another type of transfer mechanism may be employed to move substrates 100 between the chambers so that polishing apparatuses 202 in the separate chambers may be used in series or otherwise.
supported by a frame 312. The frame 312 may be coupled at one end to a polishing head drive 309. In other embodiments, the polishing arm 310 may be aligned differently, for example, vertically or at an angle with respect to the horizontal plane. The polishing arm 310 may include a polishing head section 314 ('head'). The polishing head 314 may include a plunger 316. The plunger 316 may be shaped to correspond to the shape of the notch 116, described further below. The plunger 316 may be moved towards or away from the substrate 100 by an actuator (FIG. 5) (e.g., hydraulic actuator, pneumatic actuator, servomotor, etc.). Polishing tape 318, may wrap around the polishing head 314, and guide rollers 320, 322 and over the plunger 316, and be tensioned between supply and take-up spools 324, 326. The supply and take-up spools 324, 326 may be driven by supply and take-up spool drivers 328, 330 (e.g., servomotors), respectively. The supply and take-up spool drivers 328, 330, may be moved continuously or indexed to precisely control the amount of the polishing tape 318 that is advanced over the polishing head 314 from, for example, the supply and take-up spools 324, 326, in order to polish the substrate notch 116. In some embodiments, as the polishing tape 318 advances, the polishing tape 318 may vibrate, in either a horizontal or vertical orientation, for example. Other suitable orientations may be used.

[0030] In one or more embodiments, the polishing tape 318 may be made from many different materials, such as aluminum oxide, silicon oxide, silicon carbide, etc. Other materials may also be used. In some embodiments, abrasives used may range, for example, from about 0.1 microns up to about 10 microns in size or, for example, 0.5 microns to 3 microns in size, although other sizes may be used. Different widths of polishing tape 318 ranging from about 0.55 inch to about 1.5 inches may be used. Although other polishing tape widths may be used. In one or more embodiments, the polishing tape 318 may be about 0.002 to about 0.02 inches thick and withstand about 1 to 5 lbs. in tension. Other polishing tapes having different thicknesses and tensile strengths may be used. The supply and take-up spools 324, 326 may have a diameter of approximately 3 inches and be capable of holding about 30,000 inches of polishing tape 318, or, for example, may have a diameter of approximately 1 inch and be capable of holding about 500 inches of polishing tape 318. Other spool dimensions may be used. The supply and take-up spools 324, 326 may be constructed from materials such as nylon, polyurethane, polyvinyl difluoride (PVDF), etc. Other materials may also be used.

[0031] With reference to FIG. 4, a part of the substrate 100 containing the notch 116 is schematically illustrated, not to scale. The notch 116 may include one or more notch sides 400. The notch 116 may also include a first notch corner or node 402 and a second notch corner or node 404. Each notch corner 402, 404 may be positioned at the intersection of the notch side 400 and the outer perimeter of the substrate 100. The notch 116 may further include a notch center 406, positioned at the intersection of the one or more notch sides 400. The notch center 406 may be used to align the substrate 100 during processing. As is apparent from the figure, the notch 116 may exhibit large changes in curvature as it is traced from the first notch corner 402 to the second notch corner 404, via the notch sides 400 and notch center 406. For this reason, it is advantageous to maintain consistent contact between the polishing tape 318 and all regions of the notch 116 indicated above during polishing.

[0032] Turning to FIG. 5, a schematic perspective view of a portion of an embodiment of the notch polishing apparatus 300 of FIG. 3 is provided. For reasons of clarity, only the substrate 100, the plunger 316, the polishing tape 318, and the supply and take-up spools 324, 326 are shown. In addition, it should be pointed out that the positioning of the supply and take-up spools 324, 326 shown herein is different than in the embodiment of the notch polishing apparatus 300 shown in FIG. 3.

[0033] However, the positioning of the supply and take-up spools 324, 326 may be arranged in different ways and may not have a large effect on the polishing of the notch 116. The plunger 316 may be a solid piece, resilient material, or inflatable, for example. The resilient material may be polyurethane foam or silicone rubber, for example. Other suitable materials may be used. The plunger 316 may be inflated with a pressurizable gas (e.g., air, nitrogen, carbon dioxide, etc.) or liquid (e.g., hydraulic fluid), or other suitable fluid. The plunger 316 may also be soft, rigid, and/or include or develop contours to conform to the shape of the notch 116. The radius of the plunger 316 may be selected to ensure that the polishing tape 318 is fully pushed into the notch 116 by the plunger 316. In some embodiments, the maximum radius of the plunger 316 is approximately less than 0.05 inches. In other embodiments, the maximum radius of the plunger 316 is approximately 0.03 inches or less. Any other suitable radius or dimensions may be used.

[0034] As mentioned above, the plunger 316 may be coupled to an actuator 500. The actuator 500 may be a pneumatic slide, hydraulic actuator, servomotor or any other suitable actuator 500. The actuator 500 may be mounted to the polishing head 314 or the support arm 310 for example. The operation of the actuator 500 may be controlled by the controller 206, for example. As described above with regard to FIG. 3, the plunger 316 may be moved toward or away from the substrate 100 by the actuator 500. When moved toward the substrate 100 by the actuator 500, the plunger 316 may press the polishing tape 318 into the notch 116 and cause the polishing tape 318 to conform to the shape of the notch 116 and therefore contact all of the regions of the notch 116 (FIG. 4). The actuator 500 may include an actuator force or pressure sensor 502 for measuring a force or a pressure exerted by the actuator 500 on the plunger 316. The actuator 500 may also be coupled to an actuator control unit, such as the controller 206, for example. The actuator control unit may receive a signal from the actuator force or pressure sensor 502 indicative of the force or pressure exerted on the plunger 316 by the actuator 500. The actuator control unit may also regulate the force or pressure exerted by the actuator 500 as a function of this signal. Depending on the amount of force applied to the plunger 316, the rigidity of the plunger 316 selected, the amount of inflation of the inflatable plunger 316, and/or amount of tension on the polishing tape 318, a controlled amount of pressure may be applied to polish the notch 116 as the polishing head 314 is rotated about the substrate 100.

[0035] As described above, the polishing head 314 (and therefore the plunger 316) may pivot about the substrate edge 104 and/or the notch 116. In some embodiments a center of rotation 600 (FIG. 6) of the polishing head 314 may be positioned about 0.5 inches from the substrate, on a plane that goes through a center of the thickness of the substrate 100 and is parallel to a tangent line to the circumference of the substrate 100. Other suitable center of rotation positions may be used. By positioning the center of rotation 600 a distance
from the tangent line the plunger 316 may create a flatter or less acute tape face than if the center of rotation 600 were not a distance from the tangent line. By positioning the center of rotation 600 a distance from the tangent line, the notch 116 may be more effectively polished as the polishing head 314 pivots about the notch 116. For example, in FIG. 7, the polishing head 314 has pivoted such that the polishing tape 318 is pressed into the notch 116 by an angled plunger 316. Additionally, this center of rotation position may more efficiently and effectively use the polishing tape 318, in that a greater surface area of the polishing tape 318 may contact, and therefore polish, the notch 116.

[0036] In some embodiments, one or more fluid channels (not shown) (e.g., a spray nozzle or bar) may be provided to deliver chemicals and/or water to aid in the delivering/cleaning of the notch 116, lubricate the substrate 100, and/or to wash away removed material. The fluid channel may be adapted to deliver fluid to the substrate 100 and/or to the polishing tape 318. In some embodiments, the fluid may be delivered directly to the notch 116. For example, one or more channels may be provided to direct chemicals or water to the notch 116 to assist in the polishing and/or to wash away particles resulting from the polishing. The chemicals may be sprayed directly onto the substrate 100, at the substrate-polishing tape interface. The fluids may be sprayed from either or both sides of the substrate 100 and the present invention may employ gravity or suction to cause the runoff not to contaminate or contact other parts of the substrate 100 or apparatus of the invention. Fluid also may be delivered through the movable polishing tape 318 to the notch 116. The fluids may include deionized water which may serve as a lubricant and to flush particles away. A surfactant and/or other known cleaning chemistries may also be included. In some embodiments, sonic (e.g., meegenasonic) nozzles may be used to deliver sonicated fluids to the notch 116 or substrate edge 104 to supplement the cleaning.

[0037] Turning to FIG. 8, an alternate embodiment of the apparatus 300 shown in FIG. 3 is provided. The difference between FIG. 3 and FIG. 8 is that the supply and take-up spools 324, 326 and supply and take-up spool drivers 328, 330 shown in FIG. 3 are oriented such that as the substrate 100 rotates in the x-y plane, the polishing tape 318 advances in a longitudinal direction in the plus or minus z-plane. In FIG. 8 the spools 324, 326 and spool drivers 328, 330 are oriented such that the polishing tape 318 advances in a longitudinal direction in the plus or minus y-plane.

[0038] An exemplary method 900 for cleaning and polishing the substrate notch 116 is provided in FIG. 9. In step S902, the substrate 100 may be positioned and secured on the support. In step S904, the substrate 100 is rotated until the notch 116 is in alignment with the polishing head 314, e.g., in alignment with the plunger 316. In step S906, the plunger 316 is moved in the direction of the substrate 100 by the actuator 500, until a portion of the plunger 316 is in contact with the substrate notch 116 via the polishing tape 318, and the plunger 316 presses the polishing tape 318 against the substrate notch 116. In step S908, the polishing tape 318 may advance via the supply and take-up spool drivers 328, 330.

[0039] Further with respect to the method 900 for cleaning and polishing the substrate notch 116, the pressure with which the polishing tape 318 is pressed into contact with, and against, the substrate notch 116 may be determined by the force or pressure applied to the plunger 316 by the actuator 500, the pressure of the fluid in the plunger 316, and/or the resilience of the plunger 316 and the polishing tape 318. As the polishing tape 318 is advanced over the substrate notch 116, films and imperfections on the substrate notch 116 may be removed and eliminated by abrasion. The force or pressure applied by the actuator 500, and/or the pressure of the fluid in the plunger 316, may be adjusted by an actuator control unit and a pressure control unit, respectively, as needed. In step S910, a polishing-head driver or the controller 112 may rotate or pivot the polishing head 314 about the substrate notch 116 in a plane approximately perpendicular to major surfaces 102, 102 of the substrate 100, in order to effectively clean and polish parts of the substrate notch 116 adjacent to major surfaces 102, 102 of the substrate 100. The speed, direction, tension, pressing force, etc. of the polishing tape 318 may be adjustable, as may be the rotational displacement, speed, and/or acceleration of the polishing head 314 about the substrate 100. For instance, the polishing tape 318 may be advanced at one speed for a certain length, and then another speed for another length. In addition, the polishing tape 318 may be translated or oscillated, or both, with constant or variable tensions and pressing forces.

[0040] The foregoing description discloses only exemplary embodiments of the invention. Modifications of the above disclosed apparatus and methods which fall within the scope of the invention will be readily apparent to those of ordinary skill in the art.

[0041] Accordingly, while the present invention has been disclosed in connection with exemplary embodiments thereof, it should be understood that other embodiments may fall within the spirit and scope of the invention, as defined by the following claim.

The invention claimed is:
1. An apparatus for polishing a notch of a substrate comprising:
a polishing head adapted to apply a polishing tape against the notch of the substrate, including:
a plunger; and
an actuator, wherein the actuator is adapted to move the plunger with respect to the polishing tape.
2. The apparatus of claim 1 wherein the actuator is adapted to press the plunger into polishing tape and thereby press the polishing tape against the notch.
3. The apparatus of claim 1 wherein the polishing head is adapted to pivot about the notch.
4. The apparatus of claim 1 wherein the plunger is adapted to pivot about the notch.
5. The apparatus of claim 1 wherein the polishing tape is adapted to advance over the plunger during application of the polishing tape to the notch.
6. The apparatus of claim 5 wherein the polishing tape is adapted to vibrate as the polishing tape advances over the plunger.
7. The apparatus of claim 1 wherein the plunger is adapted to conform the polishing tape to a shape of the notch.
8. The apparatus of claim 7 wherein the plunger has a shape that corresponds to a shape of the notch.
9. The apparatus of claim 1 wherein the polishing head is adapted to continuously oscillate around the notch.
10. The apparatus of claim 1 wherein the plunger is a pneumatic plunger.
11. A system for polishing a notch of a substrate comprising:
a substrate support adapted to rotate a substrate;
a polishing head adapted to apply a polishing tape against
the notch of the substrate, including:

- a plunger; and
- an actuator, wherein the actuator is adapted to press the
  plunger into polishing tape and thereby press the pol-
  ishing tape against the notch; and

- a controller adapted to operate the rotation of the sub-
  strate and the actuator.

12. The system of claim 11 wherein the controller is
adapted to incrementally advance the polishing tape to the
polishing head.

13. The system of claim 11 wherein the actuator includes a
pressure sensor adapted to sense the pressure exerted by the
actuator on the plunger.

14. The system of claim 13 wherein the controller is
adapted to receive a signal from the pressure sensor indicative
of the pressure exerted by the actuator on the plunger.

15. The system of claim 11 wherein the polishing head is
adapted to pivot about the notch.

16. The apparatus of claim 11 wherein the plunger is
adapted to pivot about the notch.

17. The apparatus of claim 11 wherein the polishing tape is
adapted to advance over the plunger during application of the
polishing tape to the notch.

18. The apparatus of claim 11 wherein the plunger is
adapted to conform the polishing tape to a shape of the notch.

19. The apparatus of claim 18 wherein the plunger has a
shape that corresponds to a shape of the notch.

20. A method for polishing a notch of a substrate compris-
ing:

- securing a substrate on a support;
- aligning a substrate notch with a polishing head including
  a plunger;
- pressing a polishing tape against a notch with the plunger;
- and
- advancing the polishing tape as the polishing tape is
  pressed against the notch.

21. The method of claim 20 further comprising:

- pivoting the polishing head about the substrate notch.

22. The method of claim 20 further comprising:

- receiving a signal indicative of the pressure applied to the
  plunger.

23. The method of claim 22 further comprising:

- adjusting the pressure based on the received signal.

24. The method of claim 20 further comprising:

- vibrating the polishing tape as the polishing tape advances.

25. The method of claim 20 further comprising:

- advancing the polishing tape continuously.