The present invention relates to methods and apparatus for improving productivity of chemical mechanical polishing (CMP) processes and lowering operating costs of CMP systems. Embodiments of the present invention provide a method for improving the ratio of the layer thickness of composite polishing pads for improved removal rates. Embodiments of the present also provide specific polishing pad identification for monitoring and controlling processes developed for the specific pad to improve overall productivity and reduce downtime of the CMP system.
FIG. 2

310 PROVIDE COMPOSITE PAD

320 VARY PAD THICKNESS

330 COMPUTE THICKNESS RATIO

340 RESCALE TO INITIAL THICKNESS

FIG. 3
CMP PAD IDENTIFICATION AND LAYER RATIO MODELING

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims benefit of U.S. provisional patent application Ser. No. 61/060,005, filed Jun. 9, 2008, which is herein incorporated by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] Embodiments of the present invention generally relate to methods and apparatus for increased productivity and decreased operating cost of a chemical mechanical polishing system.

[0004] 2. Description of the Related Art

[0005] In the fabrication of integrated circuits and other electronic devices, multiple layers of conducting, semiconducting, and dielectric materials are deposited and removed from a substrate. During integrated circuit fabrication, it is necessary to polish a surface of the substrate to remove high topography, surface defects, scratches, or embedded particles. Chemical mechanical polishing (CMP) is a common process used in polishing the surfaces of substrates for the removal of such features. Typically, CMP involves the introduction of chemical slurry during the polishing process to facilitate high removal rates and selectivity between features on the substrate surface. In general, CMP involves holding the substrate against a polishing pad under controlled pressure, temperature, and rotational velocity of the pad in the presence of the chemical slurry.

[0006] An important goal of CMP is achieving uniform planarity of the substrate surface. Uniform planarity includes the uniform removal of material from the surface of substrates as well as removing non-uniform layers which have been deposited on the substrate. Successful CMP also requires process repeatability from one substrate to the next. Thus, uniformity must be achieved not only for a single substrate, but also for a series of substrates processed in a batch.

[0007] Substrate planarity is dictated, to a large extent, by the construction of the CMP apparatus and the composition of the consumables, such as the chemical slurry and the polishing pads. A preferred construction allows for a proper balance between rigidity and compliance of the polishing device, particularly the polishing pad. Generally, stiffness is needed to ensure within-die uniformity, while sufficient compliance provides within-substrate uniformity. Within-substrate uniformity refers to the ability of the CMP apparatus to remove features across the diameter of the substrate regardless of the substrate shape and/or the topography across the surface of the substrate. Within-die uniformity refers to the ability of the CMP apparatus to remove features within a die, regardless of feature size and density.

[0008] Additionally, a successful CMP system needs to maximize the removal rate of features across the substrate. Increased removal rate without corresponding reduction in the life of consumables leads to increased production. Moreover, operating costs of a CMP system may be reduced by reducing downtime of the system, which includes maximizing pad life and accurately predicting and scheduling pad replacement intervals.

[0009] Accordingly, a need exists for a CMP system that provides increased feature removal rate, good uniformity, maximum polishing pad life, and reduced system downtime to increase system production and lower the overall operating costs of the system.

SUMMARY OF THE INVENTION

[0010] In one embodiment of the present invention, a substrate polishing apparatus comprises a platen with a polishing pad including an identification member attached to or embedded in the polishing pad and an identification member reader configured to read information from the identification member and transfer the information read from the identification member to a system controller, wherein the system controller is programmed to retrieve information specific to the polishing pad from system controller memory based on the information read from the identification member.

[0011] In another embodiment, a method for selectively improving properties of a composite polishing pad comprises selectively testing parameters of a composite polishing pad having an upper pad and a lower pad, wherein the polishing pad has an initial overall thickness, an initial upper pad thickness, an initial lower pad thickness, and wherein the parameters are selectively tested while the thickness of the lower pad is varied until desired parameter improvements are achieved, identifying an improved lower pad thickness resulting from the selectively testing composite polishing pad parameters, computing a second composite polishing pad thickness comprising the sum of the initial upper pad thickness and the improved lower pad thickness, computing a thickness ratio, wherein the thickness ratio comprises the ratio of the initial upper pad thickness to the improved lower pad thickness, and wherein the improved lower pad thickness and the improved lower pad thickness using the computed thickness ratio to achieve a final composite pad thickness substantially equal to the initial composite pad thickness.

[0012] In another embodiment, a method for selectively improving properties of a composite polishing pad comprises selectively testing parameters of a composite polishing pad having an upper pad and a lower pad, wherein the polishing pad has an initial overall thickness, an initial upper pad thickness, an initial lower pad thickness, and wherein the parameters are selectively tested while varying the thickness of the upper pad until desired parameter improvements are achieved, identifying an improved upper pad thickness resulting from the selectively testing composite polishing pad parameters, computing a second composite polishing pad thickness comprising the sum of the initial upper pad thickness and the improved upper pad thickness, computing a thickness ratio, wherein the thickness ratio comprises the ratio of the improved upper pad thickness to the initial lower pad thickness, and rescaling the initial lower pad thickness and the improved upper pad thickness using the computed thickness ratio to achieve a final composite pad thickness substantially equal to the initial composite pad thickness.

[0013] In yet another embodiment of the present invention, a polishing device comprises a polishing pad with a polishing side and a non-polishing side and an identification member attached to or embedded in the non-polishing side of the polishing pad.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] 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.

[0015] FIG. 1 is a schematic view of a chemical mechanical polishing (CMP) system, which may incorporate embodiments of the present invention.

[0016] FIG. 2 is a schematic cross-sectional view of a polishing apparatus.

[0017] FIG. 3 is a flow chart illustrating a process for improving the thickness ratio of a composite polishing pad to improve a particular performance parameter and rescaling the pad for use in an existing CMP system according to the present invention.

[0018] FIGS. 4A, 4B, and 4C depict a simplified example of the process 300.

[0019] FIG. 5 is a schematic representation of a CMP apparatus including pad identification components according to embodiments of the present invention.

DETAILED DESCRIPTION

[0020] The present invention relates to methods and apparatus for improving productivity of chemical mechanical polishing (CMP) processes and lowering operating costs of CMP systems. Embodiments of the present invention provide a method for improving the ratio of the layer thickness of composite polishing pads for improved removal rates. Embodiments of the present also provide specific polishing pad identification for monitoring and controlling processes developed for the specific pad to improve overall productivity and reduce downtime of the CMP system.

[0021] FIG. 1 is a schematic view of a CMP system 100, which may incorporate embodiments of the present invention. The CMP system 100 may include a lower machine base 122 with a tabletop 128 mounted thereon with a removable outer cover (not shown). The tabletop 128 supports a series of polishing stations, which may include a first polishing station 125, a second polishing station 125, a third polishing station 125, and a transfer station 127. The transfer station 127 may serve multiple functions, including receiving individual substrates 110 from a loading apparatus (not shown), washing the substrates 110, loading the substrates 110 into carrier heads 180, receiving the substrates 110 from the carrier heads 180, and transferring the substrates 110 to the loading apparatus.

[0022] Each polishing station 125 may include a rotatable platen 130 having a polishing pad 120 attached thereto. Each platen 130 may be a rotatable aluminum or stainless steel platen attached to a platen drive motor (not shown). In one embodiment, the first polishing station 125 has a first polishing pad 120 disposed on a platen 130. The platen 130 may be adapted for polishing the substrate 110 to substantially remove bulk copper-containing material disposed on the substrate 110. The second polishing station 125 may have a second polishing pad 120 disposed on the platen 130 for polishing the substrate 110 to remove residual copper-containing material disposed on the substrate 110. The third polishing station 125 may have a polishing pad 120 disposed on the platen 130 for polishing the substrate 110 to remove barrier layer material disposed on the substrate 110.

[0023] In one embodiment, the polishing stations 125 each include a pad conditioner apparatus 140. The pad conditioner apparatus 140 may have a rotatable arm 142 holding an independently rotating conditioner head 144 and an associated washing basin 146. The pad conditioner apparatus 140 maintains the condition of the polishing pad 120 so that it will effectively polish the substrates 110.

[0024] In one embodiment, the polishing stations 125 each have a composition delivery/rinse arm 152 that includes two or more supply tubes to provide one or more CMP compositions, cleaning compositions, and/or water to the surface of the polishing pad 120. The composition delivery/rinse arm 152 delivers the one or more chemical slurries in amounts sufficient to cover and wet the entire polishing pad. Each composition delivery/rinse arm 152 also includes several spray nozzles (not shown) that can provide a high pressure fluid rinse onto the polishing pad 120 at the end of each polishing and conditioning cycle. Additionally, intermediate washing stations 155 may be positioned between adjacent polishing stations 125 to clean the substrate 110 as it passes from one station to the next.

[0025] In one embodiment, a rotatable multi-head carousel 160 is positioned above the lower machine base 122. The carousel 160 may include four carrier head systems 170. Three carrier head systems 170 receive or hold the substrates 110 and press them against the polishing pads 120 disposed on the polishing stations 125. One of the carrier head systems 170 receives the substrate 110 from and delivers the substrate 110 to the transfer station 127. The carousel 160 may be supported by a center post 162 and rotated about a carousel axis 164 by a motor assembly (not shown) located within the machine base 122. The center post 162 may also support a carousel support plate 166 and a cover 188.

[0026] In one embodiment, the four carrier head systems 170 are mounted on the carousel support plate 166 at equal angular intervals about the carousel axis 164. The carousel post 162 allows the carousel motor to rotate the carousel support plate 166 and orbit the carrier head systems 170 about the carousel axis 164. Each carrier head system 170 includes one carrier head 180. A carrier drive shaft 178 connects a carrier head rotation motor 176 (shown by the removal of one quarter of the cover 188) to the carrier head 180 so that the carrier head 180 can independently rotate about its own axis. Additionally, each carrier head 180 may independently oscillate laterally in a radial slot 172 formed in the carousel support plate 166.

[0027] The carrier head 180 may perform several functions. The carrier head 180 may comprise a vacuum mechanism to chuck the substrate 110. During operation, the carrier head 180 generates negative pressure behind the surface of the substrate 110 to attract and hold the substrate 110. Additionally, the carrier head 180 holds the substrate 110 against the polishing pads 120, evenly distributing a downward pressure across the back surface of the substrate 110. The carrier head 180 further transfers torque from the drive shaft 178 to the substrate 110 and ensures that the substrate 110 does not slip out from beneath the carrier head 180 during CMP operations.

[0028] In one embodiment, the CMP system 100 is equipped with a system controller 190 programmed to control and carry out various methods and sequences. The system controller 190 generally facilitates the control and automation of the overall system and may include a central processing unit (CPU) 192, memory 194, and support circuits 196. The CPU 192 may be one of many computer processors used in industrial settings for controlling various system functions and processes.

[0029] In one embodiment, the polishing pad 120 may comprise two pads assembled together into a stack, called a composite polishing pad. FIG. 2 is a schematic cross-sectional view of a polishing apparatus 200, such as polishing station 125. The polishing apparatus 200 includes a metal platen 230, such as platen 130, having a composite polishing pad 220 mounted thereto. Both the composite polishing pad 220 and the platen 230 are generally disc-shaped and of substantially equal diameters. The composite polishing pad
comprises an upper pad 260 and a lower pad 280. An adhesive 250, such as a pressure sensitive adhesive (PSA) is provided on the back face of the pads 260, 280 to bond the pads to one another and to the platen 230, respectively.

Generally, it is preferable that the upper pad 260 be stiffer and less compliant than the lower pad 280 to provide a sufficiently rigid polishing surface. Typically, a stiff pad provides better within-die uniformity, while more compliance is needed to ensure within-substrate uniformity. In one embodiment, the upper pad 260 comprises polyurethane. In one embodiment, the lower pad 280 comprises polyester felt stiffened with polyurethane resin. The combination of pads 260, 280 having the proper proportions of stiffness and compliance achieve good planarity and uniformity over the surface of the substrate.

It has been discovered that improvements to the CMP process may be achieved by varying the ratio of the thickness of the upper pad 260 with respect to the thickness of the lower pad 280 without altering the density, compressibility, or other properties of the individual pads 260, 280. In one embodiment, the thickness ratio of the composite pad 220 may be modified to maximize the removal rate of particular films or features on the substrate when the composite pad 220 is used in combination with a particular recipe of chemical slurry. Once determined, the thickness ratio of the composite pad 220 may be used to re-scale the overall thickness of the composite pad 220 for use in existing CMP systems.

FIG. 3 is a flow chart illustrating a process 300 for improving the thickness ratio of a composite polishing pad to improve a particular performance parameter and re-scaling the pad for use in an existing CMP system. At 310, a composite pad, such as composite pad 220, with a stiff upper pad, such as pad 310, and a compliant lower pad, such as pad 280, and having an initial overall thickness is provided with baseline performance parameters for a given recipe of chemical slurry. At 320, the thickness of the lower pad of the composite pad is increased and/or decreased, while maintaining a constant thickness in the upper pad, until a range of desired results are achieved for the given recipe of chemical slurry without altering the individual physical properties of the lower pad or the upper pad. In one embodiment, the thickness of the upper pad may be altered while maintaining the thickness of the lower pad. In another embodiment, both the upper and lower pad thickness may be altered. Once the desired range of results is found, the ratio of the thickness of the upper pad to the thickness of the lower pad is computed at 330. At 340, the overall thickness of the composite pad is re-scaled to a thickness of the initial overall thickness in 310 within a specified tolerance required for using the pad in the existing CMP system, while keeping the upper to lower pad thickness ratio computed in 330.

FIGS. 4a, 4b, and 4c depict a simplified example of the process 300. As shown in FIG. 4a, a composite pad 400 having an initial overall thickness 400a of about 13 mm has an upper pad 460 with an initial upper thickness 460a of about 8 mm and a lower pad 480 with an initial lower thickness 480a of about 5 mm. The thickness of the lower pad 480 is selectively increased during testing to increase removal rate without affecting substrate uniformity. As shown in FIG. 4b, it is found that a lower pad thickness increase 480b of between about 6 mm to about 9 mm yields a removal rate increase of between about 6% to about 15% without affecting substrate uniformity. Therefore, the ratio of the thickness of the upper pad 460 to the thickness of the lower pad 480 is between about 0.73 to about 0.57. FIG. 4c depicts the rescaled composite pad 400 having a final overall thickness 400b substantially the same as the initial overall thickness 400a and thicknesses ranging from a final upper pad thickness 460c of about 4 mm and a final lower pad thickness 480c of about 7 mm to a final upper pad thickness 460c of about 5.8 mm to a final lower pad thickness 480c of about 8 mm.

Additionally, improvements in CMP productivity and operating costs may be achieved by providing information about a specific polishing pad to a system controller of a CMP apparatus. In one embodiment, shown in FIG. 5, an identification member 523 is attached to or embedded in polishing pad 520. The identification member 523 provides specific information about the polishing pad 520 to a system controller 520 of a CMP apparatus 500 via an identification reader 595. In operation, the identification reader 595 identifies the specific polishing pad 520 by reading the information stored in the identification member 523. The system controller 590, which is pre-programmed with information regarding specific polishing pads, retrieves information regarding the polishing pad 520 identified by the identification member 523 for use in CMP processes with the specific polishing pad 520.

In one embodiment, the identification member 523 is a barcode imprinted on the polishing pad 520 during its fabrication, and the identification reader 595 is a scanner that scans the barcode and relays the information about the specific polishing pad 520 to the system controller 590 via circuitry 596. In one embodiment, the identification member 523 is a barcode imprinted on the non-polishing side of the polishing pad 520. In another embodiment, the identification member 523 is a radio frequency identification (RFID) tag, and the identification reader 595 is an RFID tag reader. In one embodiment, the identification member 523 is an RFID tag attached to the non-polishing side of the polishing pad 520. In one embodiment, the identification member 523 is an RFID tag embedded within the non-polishing side of the polishing pad 520. In one embodiment, the polishing pad 520 is spin-balanced after installing the identification member 523 and prior to installing in CMP apparatus 500.

In one embodiment, once the system controller 590 identifies the specific polishing pad 520, specific information about the polishing pad 520 identified is accessed for use in the CMP process. In one embodiment, information regarding specific polishing pad “burn-in” processes and recipes is accessed, which leads to increased overall productivity and life of the polishing pad 520. In one embodiment, information regarding proper CMP processes and recipes is accessed specific to maximizing productivity and life of the specific polishing pad 520. In one embodiment, information regarding the specific polishing pad’s specific material properties and life is accessed for controlling CMP processes, such as platen rotation speed, chemical slurry delivery rate, and pad conditioning parameters. In one embodiment, wear rate and pad life of specific polishing pads 520 are tracked, and maintenance and/or replacement schedules are refined to reduce CMP apparatus downtime. In one embodiment, pad life versus number of substrates is monitored for specific polishing pads 520 for refining CMP procedures and chemical slurry recipes. In one embodiment, wear rate and other operating information for specific polishing pads 520 is tracked and used for identifying and troubleshooting excessive pad wear situations.

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. A substrate polishing apparatus, comprising:
a platen with a polishing pad including an identification
member attached to or embedded in the polishing pad; and
an identification member reader configured to read infor-
mation from the identification member and transfer the
information read from the identification member to a
system controller, wherein the system controller is pro-
grammed to retrieve information specific to the polish-
ing pad from system controller memory based on the
information read from the identification member.

2. The apparatus in claim 1, wherein the identification
member is a barcode, and wherein the identification member
reader is a barcode scanner.

3. The apparatus in claim 1, wherein the identification
member is a radio frequency identification tag, and wherein
the identification member reader is a radio frequency iden-
tification tag reader.

4. The apparatus of claim 1, wherein the system controller
is further programmed to use the retrieved information for
controlling polishing processes.

5. The apparatus of claim 1, further comprising a composi-
tion delivery device, wherein the system controller is further
programmed to use the retrieved information to control the
delivery rate of composition delivered by the composition
delivery device.

6. The apparatus of claim 5, wherein the system controller
is further programmed to use the retrieved information to
control a chemical slurry recipe delivered by the composition
delivery device.

7. The apparatus of claim 1, wherein the system controller
is further programmed to retrieve information specific to
burning in the polishing pad and to control a burn in procedure
for the polishing pad using the retrieved information.

8. The apparatus of claim 1, further comprising a polishing
pad conditioning apparatus, wherein the system controller is
further programmed to use the retrieved information to con-
trol parameters of the polishing pad conditioning apparatus.

9. The apparatus of claim 1, wherein the polishing pad is a
composite polishing pad, comprising:
an upper polishing pad; and
a lower polishing pad, wherein the lower polishing pad is
more compliant than the upper polishing pad, and
wherein the ratio of the thickness of the upper polishing
pad to the thickness of the lower polishing pad is
between about 0.73 to about 0.57.

10. A method for selectively improving properties of a
composite polishing pad, comprising:
selectively testing parameters of a composite polishing pad
having an upper pad and a lower pad, wherein the pol-
ishing pad has an initial overall thickness, an initial
upper pad thickness, and an initial lower pad thickness,
and wherein the parameters are selectively tested while
the thickness of the lower pad is varied until desired
parameter improvements are achieved;
identifying an improved lower pad thickness resulting
from the selectively testing composite polishing pad
parameters;
computing a second composite polishing pad thickness
comprising the sum of the initial upper pad thickness and the improved lower pad thickness;
computing a thickness ratio, wherein the thickness ratio
comprises the ratio of the initial upper pad thickness to the
improved lower pad thickness; and
resealing the initial upper pad thickness and the improved
lower pad thickness using the computed thickness ratio
to achieve a final composite pad thickness substantially
equal to the initial composite pad thickness.

11. The method of claim 10, wherein the varying the thick-
ness of the lower pad comprises increasing the thickness of
the lower pad.

12. The method of claim 10, wherein the polishing pad
parameters comprise a feature removal rate for a given chemi-
cal slurry recipe.

13. A method for selectively improving properties of a
composite polishing pad, comprising:
selectively testing parameters of a composite polishing pad
having an upper pad and a lower pad, wherein the pol-
ishing pad has an initial overall thickness, an initial
upper pad thickness, and an initial lower pad thickness,
and wherein the parameters are selectively tested while
the thickness of the lower pad is varied until desired
parameter improvements are achieved;
identifying an improved upper pad thickness resulting
from the selectively testing composite polishing pad
parameters;
computing a second composite polishing pad thickness
comprising the sum of the initial lower pad thickness and the improved lower pad thickness;
computing a thickness ratio, wherein the thickness ratio
comprises the ratio of the initial upper pad thickness to the
improved lower pad thickness; and
resealing the initial lower pad thickness and the improved
lower pad thickness using the computed thickness ratio
to achieve a final composite pad thickness substantially
equal to the initial composite pad thickness.

14. The method of claim 13, wherein the varying the thick-
ness of the upper pad comprises increasing the thickness of
the upper pad.

15. The method of claim 13, wherein the polishing pad
parameters comprise a feature removal rate for a given chemi-
cal slurry recipe.

16. A polishing device, comprising:
a polishing device, comprising:
an upper polishing pad; and
a lower polishing pad, wherein the lower polishing pad is
more compliant than the upper polishing pad, and
wherein the ratio of the thickness of the upper polishing
pad to the thickness of the lower polishing pad is
between about 0.73 and about 0.57.

17. The polishing device of claim 16, wherein the polishing
pad is a composite polishing pad, comprising:
an upper polishing pad; and
a lower polishing pad, wherein the lower polishing pad is
more compliant than the upper polishing pad, and
wherein the ratio of the thickness of the upper polishing
pad to the thickness of the lower polishing pad is
between about 0.73 and about 0.57.

18. The polishing device of claim 17, wherein the identifi-
cation member is a barcode imprinted on the non-polishing
side of the polishing pad.

19. The polishing pad of claim 17, wherein the identifi-
cation member is a radio frequency identification tag embedded
within the non-polishing side of the polishing pad.

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