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Inventor(s)

CHEN; Yen-Liang et al.

CHEMICAL MECHANICAL POLISHING APPARATUS AND METHOD

Abstract

A polish head of a chemical mechanical polishing system is provided. The polish head includes a carrier head, a membrane mounted to the carrier head, an inner retaining ring mounted to the carrier head and surrounding the membrane, an outer retaining ring mounted to the carrier head and surrounding the inner retaining ring, and an image capturing device. The outer retaining ring is spaced apart from the inner retaining ring. The image capturing device is mounted to the carrier head and between the inner retaining ring and the outer retaining ring.

Inventors: CHEN; Yen-Liang (Taichung City, TW), LIU; Jun-Xiu (Taichung City, TW), CHOU; Chia-Hsien (Changhua County, TW)

Applicant: TAIWAN SEMICONDUCTOR MANUFACTURING CO., LTD. (Hsinchu, TW)

Family ID: 70328035

Assignee: TAIWAN SEMICONDUCTOR MANUFACTURING CO., LTD. (Hsinchu, TW)

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION [0001] This application is a divisional application of U.S. application Ser. No. 16/657,161, filed on Oct. 18, 2019, which claims priority to U.S. Provisional Application Ser. No. 62/751,725, filed Oct. 29, 2018, which are herein incorporated by references in their entireties.

BACKGROUND

[0002] Generally, semiconductor devices include active components, such as transistors, formed on a substrate. Any number of interconnect layers may be formed over the substrate connecting the active components to each other and to outside devices. The interconnect layers are made of low-k dielectric materials including metallic trenches/vias.

[0003] As the layers of a device are formed, it is sometimes desirable to planarize the device. For example, the formation of metallic features in the substrate or in a metal layer may cause uneven topography. This uneven topography creates difficulties in the formation of subsequent layers. For example, uneven topography may interfere with the photolithographic process used to form various features in a device. It is, therefore, desirable to planarize the surface of the device after various features or layers are formed. One method of planarization is chemical mechanical polishing (CMP).

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] Aspects of the present disclosure are best understood from the following detailed description when read with the accompanying figures. It is noted that, in accordance with the standard practice in the industry, various features are not drawn to scale. In fact, the dimensions of the various features may be arbitrarily increased or reduced for clarity of discussion.

[0005] FIG. 1 is a schematic view of a chemical mechanical polishing (CMP) system according to some embodiments of the present disclosure.

[0006] FIG. 2 is a top view of the CMP system of FIG. 1.

[0007] FIG. 3 is a cross-sectional view of the polish head of FIG. 1.

[0008] FIG. 4 is a bottom view of the polish head of FIG. 1.

[0009] FIG. 5 is a cross-sectional view taken along line 5 of FIG. 4.

[0010] FIG. 6 is a bottom view of the polish head, according to some other embodiments of the present disclosure.

[0011] FIG. 7 is a flowchart of a method for operating the CMP system of FIG. 1.

DETAILED DESCRIPTION

[0012] The following disclosure provides many different embodiments, or examples, for implementing different features of the provided subject matter. Specific examples of components and arrangements are described below to simplify the present disclosure. These are, of course, merely examples and are not intended to be limiting. For example, the formation of a first feature over or on a second feature in the description that follows may include embodiments in which the first and second features are formed in direct contact, and may also include embodiments in which additional features may be formed between the first and second features, such that the first and second features may not be in direct contact. In addition, the present disclosure may repeat reference numerals and/or letters in the various examples. This repetition is for the purpose of

simplicity and clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed.

[0013] Further, spatially relative terms, such as “beneath,” “below,” “lower,” “above,” “upper” and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. The spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. The apparatus may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein may likewise be interpreted accordingly.

[0014] FIG. 1 is a schematic view of a chemical mechanical polishing (CMP) system **100** according to some embodiments of the present disclosure. FIG. 2 is a top view of the CMP system **100** of FIG. 1. The CMP system **100** is configured to perform a planarization process on a wafer **10** in a semiconductor manufacturing process. The CMP system **100** includes a platen **110**, a polish pad **120**, a polish head **200**, a conditioner **140**, and a slurry dispenser **150** in accordance with some embodiments of the present disclosure. The platen **110** is driven by a motor to rotate the polish pad **120** about a rotation axis. In some embodiments, the platen **110** is circular, in a top view. The diameter of the platen **110** is larger than the diameter of the wafer **10** to be polished.

[0015] The polish pad **120** is disposed on the platen **110**. The polish pad **120** may be a consumable item. The polish pad **120** may be a hard and incompressible pad or a soft pad. For oxide polishing, hard and stiffer pads may be used to achieve planar surfaces. Softer pads may be used in other polishing processes to achieve uniform and smooth surfaces. The hard pads and the soft pads may also be combined in an arrangement of stacked pads for customized applications.

[0016] The polish head **200** is configured to house the wafer **10**. In some embodiments, the polish head **200** includes a carrier head **210**, a membrane **240**, and at least one retaining ring. In some embodiments, the retaining ring includes an outer retaining ring **230** and an inner retaining ring **220**. The inner retaining ring **220** is disposed between the outer retaining ring **230** and the membrane **240**. The outer retaining ring **230** and the inner retaining ring **220** can adjust a surface profile of the polish pad **120** and control the wafer edge profile.

[0017] The carrier head **210** picks up the wafer **10** from a stage, e.g., using vacuum suction on the membrane **240**. The carrier head **210** carries the wafer **10** to the polish pad **120**, and the carrier head **210** is lowered towards the polish pad **120** to polish the wafer **10**. The membrane **240** under the carrier head **210** is pressurized to push the wafer **10** towards the polish pad **120**. The wafer **10** is polished by rotating the polish pad **120** (and/or the carrier head **210**). The wafer **10** may have various device elements thereon. Examples of device elements that are formed on the wafer **10** include transistors (e.g., metal oxide semiconductor field effect transistors (MOSFETs), complementary metal oxide semiconductor (CMOS) transistors, bipolar junction transistors (BJTs), high voltage transistors, high-frequency transistors, p-channel and/or n-channel field-effect transistors (PFETs/NFETs), etc.), diodes, and/or other suitable elements. Various processes may be performed to form the device elements, such as deposition, etching, implantation, photolithography, annealing, and/or other suitable processes. In some embodiments, shallow trench isolation (STI) structures, inter-layer dielectric (ILD) layers, and/or inter-metal dielectric layers may also be formed in or on the wafer **10**.

[0018] The conditioner **140** is configured to condition the polish pad **120**. In some embodiments, the conditioner **140** includes a conditioning arm **142** and a conditioning pad **144**. The conditioning arm **142** holds the conditioning pad **144** which is in contact with the polish pad **120** during the planarization process. The conditioning arm **142** moves the conditioning pad **144** in a sweeping motion across a region of the polish pad **120**. The conditioning pad **144** includes a substrate over which an array of abrasive particles, such as diamonds, is bonded using, for example, electroplating. The conditioning pad **144** removes built-up wafer debris and excess slurry from the polish pad **120**. The conditioning pad **144** also acts as an abrasive for the polish pad **120** to create

an appropriate texture against which the wafer **10** may be properly planarized.

[0019] The slurry dispenser **150** includes a dispenser arm **152** and a number of nozzles **154**. The nozzles **154** are arranged on a bottom surface of the dispenser arm **152** and are configured to supply slurry **20** over the polish pad **120**. The composition of the slurry **20** supplied by the slurry dispenser **150** depends on the type of material on the wafer surface undergoing the CMP. For example, tungsten slurries may be acidic to enhance the chemical etching effect on tungsten films, while copper slurries may be basic to minimize corrosion of copper films.

[0020] In some embodiments, one or more elements can be added to or omitted from the CMP system **100**. For example, an atomizer nozzle can be added to the CMP system **100** and is configured to supply a high pressure rinse over the polish pad **120**, thereby cleaning the polish pad **120**.

[0021] Reference is now made to FIG. **3** and FIG. **4**. FIG. **3** is a cross-sectional view of the polish head **200** of FIG. **1**. FIG. **4** is a bottom view of the polish head **200** of FIG. **1**. The polish head **200** includes a carrier head **210**, an inner retaining ring **220**, an outer retaining ring **230**, a membrane **240**, and an image capturing device **250**. The carrier head **210** is configured to accommodate a wafer therein. The inner retaining ring **220** and outer retaining ring **230** are configured to retain the wafer in a horizontal position. The membrane **240** is configured to secure the wafer, and pressing the wafer in a downward direction.

[0022] The inner retaining ring **220** and the outer retaining ring **230** are concentrically arranged. The membrane **240** is mounted to the carrier head **210**. The inner retaining ring **220** is mounted to the carrier head **210** and surrounds the membrane **240**. The outer retaining ring **230** is mounted to the carrier head **210** and surrounds the inner retaining ring **220**. The outer retaining ring **230** is spaced apart from the inner retaining ring **220**. The outer retaining ring **230** is formed with a wall portion **232** and a ledge portion **234**. The ledge portion **234** horizontally extends from the wall portion **232** toward the inner retaining ring **220**, and a bottom surface of the ledge portion **234** is substantially coplanar with a bottom surface of the wall portion **232**. During the CMP process, the ledge portion **234** of the outer retaining ring **230** may be in contact with the inner retaining ring **220** and is configured to retain the inner retaining ring **220** in a horizontal position by restricting the horizontal movement of the inner retaining ring **220**. The inner retaining ring **220** in turn is configured to retain the wafer in a horizontal position by restricting the horizontal movement of the wafer. An inner sidewall **236** of the wall portion **232** of the outer retaining ring **230** that faces the inner retaining ring **220** and an outer sidewall **222** of the inner retaining ring **220** that faces the outer retaining ring **230** define a gap **G** therebetween.

[0023] In some embodiments, the inner retaining ring **220** includes polyurethane, polyester, polyether, polycarbonate, any combination thereof, or any other suitable material. In some embodiments, the outer retaining ring **230** includes polyether ether ketone (PEEK), polyphenylene sulfide (PPS), any combination thereof, or any other suitable material. In some embodiments, the inner retaining ring **220** is softer than the outer retaining ring **230** in hardness. In some embodiments, the inner retaining ring **220** has a hardness ranging from about 15 to about 105 in Shore A hardness scale and the outer retaining ring **230** has a hardness ranging from about 95 to about 110 in Rockwell M hardness scale. The softer inner retaining ring **220** absorbs impact/contact energy and reduces vibrations between the inner retaining ring and the wafer during the CMP process and prevents damage/peeling on the wafer.

[0024] The Shore hardness is a measure of the resistance of a material to penetration of a calibrated spring loaded needle-like indenter, measured by using a durometer. The hardness of polymers (rubbers, plastics) is measured by Shore scales. The Rockwell hardness is measured by indenting the test material with a diamond cone or hardened steel ball indenter. The indenter is forced into the test material under a preliminary minor load and the application and removal of an additional major load results in a permanent increase in the depth of penetration that is used to calculate the Rockwell hardness number.

[0025] In some embodiments, the inside diameter of the inner retaining ring **220** ranges from about 300 mm to about 303 mm, and the outside diameter of the outer retaining ring **230** ranges from about 329 mm to about 333 mm. In some other embodiments, the sizes of the inner retaining ring **220** and the outer retaining ring **230** can be different to accommodate a larger or smaller wafer during a CMP process or other processes requiring the wafer to be retained during a process step.

[0026] In some embodiments, the inner retaining ring **220** has a thickness ranging from about 31 mm to about 35 mm. In some embodiments, the outer retaining ring **230** has a thickness ranging from about 25 mm to about 28 mm. In some embodiments, the thickness of the inner retaining ring **220** is thicker than the thickness of the outer retaining ring **230**, and the thickness difference thereof is in a range from about 6 mm to about 8 mm. If the thickness difference between the inner retaining ring **220** and the outer retaining ring **230** is greater than about 8 mm, the inner retaining ring **220** might be too thick, such that a contact area between the inner retaining ring **220** and the polish pad might be too large, and thus unwanted particles might be formed due to friction between the inner retaining ring **220** and the polish pad. If the thickness difference between the inner retaining ring **220** and the outer retaining ring is smaller than about 6 mm, the inner retaining ring **220** might be too thin to have satisfactory mechanical strength.

[0027] In some embodiments, the inner retaining ring **220** and the outer retaining ring **230** are both attached to the bottom surface of the carrier head **210** using an adhesive (glue) layer.

[0028] However, during the CMP process, the ledge portion **234** of the outer retaining ring **230** may get worn out due to friction between the ledge portion **234** of the outer retaining ring **230** and the inner retaining ring **220**, and the wall portion **232** of the outer retaining ring **230** may undesirably contact the inner retaining ring **220**. In this case, the contact between the wall portion **232** of the outer retaining ring **230** and the inner retaining ring **220** results in undesired friction between the wall portion **232** of the outer retaining ring **230** and the inner retaining ring **220**. The undesired friction between the wall portion **232** of the outer retaining ring **230** and the inner retaining ring **220** may result in defects on the wafer. In some embodiments, the gap G between the inner sidewall **236** of the wall portion **232** of the outer retaining ring **230** and the outer sidewall **222** of the inner retaining ring **220** is in a range from about 1.37 mm to about 2.06 mm to prevent the wall portion **232** of the outer retaining ring **230** from undesirably contacting the inner retaining ring **220**.

[0029] In some embodiments, the image capturing device **250** of the polish head **200** is mounted to the carrier head **210** and arranged inside the gap G between the outer retaining ring **230** and the inner retaining ring **220** and is configured to capture images of a top surface **238** of the ledge portion **234** of the outer retaining ring **230**, the inner sidewall **236** of the wall portion **232** of the outer retaining ring **230**, and the outer sidewall **222** of the inner retaining ring **220**. For example, in some embodiments, at least a portion of the image capturing device **250** is directly above the ledge portion **234**.

[0030] In some embodiments, the captured images are analyzed to determine whether a width W of the ledge portion **234** of the outer retaining ring **230** is less than a predetermined value. When the width W of the ledge portion **234** of the outer retaining ring **230** is determined to be less than the predetermined value, an alarm is reported. In some embodiments, preventive maintenance is performed to replace the outer retaining ring **230** when the alarm is reported.

[0031] In some embodiments, the width W of the ledge portion **234** of the outer retaining ring **230** is in a range from about 0.77 mm to about 1.26 mm to prevent the wall portion **232** of the outer retaining ring **230** from undesirably contacting the inner retaining ring **220**. If the width W of the ledge portion **234** of the outer retaining ring **230** is less than about 0.77 mm, then the outer retaining ring **230** is determined to be worn out, and an alarm is reported. In some embodiments, preventive maintenance is performed to replace the outer retaining ring **230** when the alarm is reported.

[0032] In some embodiments, the captured images are analyzed to determine whether a distance d

between a sidewall of the ledge portion **234** of the outer retaining ring **230** and the outer sidewall **222** of the inner retaining ring **220** is greater than a predetermined value. When the distance d between the sidewall of the ledge portion **234** of the outer retaining ring **230** and the outer sidewall **222** of the inner retaining ring **220** is determined to be greater than the predetermined value, an alarm is reported. In some embodiments, preventive maintenance is performed to replace the inner retaining ring **220** and/or the outer retaining ring **230** when the alarm is reported.

[0033] In some embodiments, the distance d between the sidewall of the ledge portion **234** of the outer retaining ring **230** and the outer sidewall **222** of the inner retaining ring **220** is in a range from about 0.6 mm to about 0.8 mm to prevent the wall portion **232** of the outer retaining ring **230** from undesirably contacting the inner retaining ring **220**. If the distance d between the sidewall of the ledge portion **234** and the outer sidewall **222** of the inner retaining ring **220** is determined to be greater than 0.9 mm; and/or the ratio of the width W to the distance d is determined to be less than about 0.3, the inner retaining ring **220** and/or the outer retaining ring **230** are/is determined to be worn out, and an alarm is reported. In some embodiments, preventive maintenance is performed to replace the inner retaining ring **220** and/or the outer retaining ring **230** when the alarm is reported.

[0034] Other features that can be observed from the captured images include roughness of the inner sidewall **236** of the wall portion **232** of the outer retaining ring **230**, roughness of the outer sidewall **222** of the inner retaining ring **220**, a slant angle of the inner sidewall **236** of the wall portion **232** of the outer retaining ring **230**, and a slant angle of the outer sidewall **222** of the inner retaining ring **220**. If the roughness of the inner sidewall **236** of the wall portion **232** of the outer retaining ring **230**, the roughness of the outer sidewall **222** of the inner retaining ring **220**, the slant angle of the inner sidewall **236** of the wall portion **232** of the outer retaining ring **230**, and/or the slant angle of the outer sidewall **222** of the inner retaining ring **220** are/is determined to be unacceptable, then the inner retaining ring **220** and/or the outer retaining ring **230** are/is determined to be worn out, and an alarm is reported. In some embodiments, preventive maintenance is performed to replace the inner retaining ring **220** and/or the outer retaining ring **230** when the alarm is reported.

[0035] Furthermore, the inner retaining ring **220** has indented slots **260** in a bottom surface of the inner retaining ring **220**, and the outer retaining ring **230** has indented slots **262** in a bottom surface of the outer retaining ring **230**. The indented slots **262** of the outer retaining ring **230** are respectively substantially aligned with the indented slots **260** of the inner retaining ring **220** to form continuous channels that allows slurry to flow towards the wafer during the CMP process. In some embodiments, the indented slots **262** of the outer retaining ring **230** may have a width greater than a width of the indented slots **260** of the inner retaining ring **220**. However, as slurry flows through the channel, it passes through the gap G between the outer retaining ring **230** and the inner retaining ring **220**, and may undesirably seep into the gap G , leaving behind a contaminant residue inside the gap G between the outer retaining ring **230** and the inner retaining ring **220**. The contaminant residue inside the gap G between the outer retaining ring **230** and the inner retaining ring **220** may also result in defects on the wafer.

[0036] In some embodiments, the captured images are analyzed to determine whether the contaminant residue inside the gap G exceeds a predetermined threshold. An alarm is reported when the contaminant residue inside the gap G is determined to exceed the predetermined threshold. In some embodiments, a clean process is performed on the polish head **200** to remove the contaminant residue from the gap G when the alarm is reported.

[0037] In some embodiments, because a portion of the contaminant residue inside the gap G is deposited on the top surface **238** of the ledge portion **234** of the outer retaining ring **230**, the captured images are analyzed to determine whether the contaminant residue on the top surface **238** of the ledge portion **234** of the outer retaining ring **230** exceeds a predetermined threshold. An alarm is reported when the contaminant residue on the top surface **238** of the ledge portion **234** of the outer retaining ring **230** is determined to exceed the predetermined threshold. In some embodiments, a clean process is performed on the polish head **200** to remove the contaminant

residue from the gap G when the alarm is reported.

[0038] In some embodiments, the gap G is in fluid communication with the indented slot **260** of the inner retaining ring **220** and the indented slot **262** of the outer retaining ring **230** at a junction. The image capturing device **250** is configured such that the image capturing device **250** is able to capture an image of a portion of the gap G adjacent to the junction. For example, in some embodiments, the image capturing device **250** is coupled to a rail **265** that allows the image capturing device **250** to move to a position immediately adjacent to the junction. In some other embodiments, the image capturing device **250** is disposed at a position immediately adjacent to the junction (as shown in FIG. 6).

[0039] In some embodiments, the image capturing device **250** is a large active area image sensor. For example, image capturing device **250** can be a photodiode, such as an indium gallium arsenide (InGaAs) photodiode. The InGaAs photodiode can detect images in conditions of low lighting, making it suitable for capturing images inside the gap G. The detected image is stored as a grayscale image with 16 bits per pixel sample or higher. In other words, each pixel in the stored image can be represented by 216 or 65,536 levels of light intensities or higher. The intensities at the corresponding pixels may not be spaced in linear proportion to the detected physical light. Instead, they may be spread out evenly on a gamma-compressed nonlinear scale to create a smoother image with no noticeably discontinuous pixels. The resulting stored image shows a clear contrast of details.

[0040] In some embodiments, the image capturing device **250** may use high dynamic range. A high dynamic range displays image features having clear boundaries and having a range of luminance similar to the range of luminance visible to the human eye. As such, the displayed image is easy for the human eye to interpret and identify features detected by the image capturing device **250**.

[0041] In some embodiments, images captured by the image capturing device **250** are processed by a processor **255**. The processor **255** is configured to process the captured images to calculate the level of wear on the outer retaining ring **230**, such as the level of wear on the ledge portion **234** of the outer retaining ring **230**. In some embodiments, the image capturing device **250** is configured to scan a target region, and the processor **255** is configured to calculate an area of the largest object in the target region. If the target region is in the gap G between the inner retaining ring **220** and the outer retaining ring **230**, then the area of the largest object in the target region is an area of the top surface **238** of the ledge portion **234** of the outer retaining ring **230**. However, if the ledge portion **234** of the outer retaining ring **230** is worn out, then the area of the top surface **238** of the ledge portion **234** is substantially reduced. As such, the area of the largest object in the target region is reduced. By calculating the area of the largest object in the target region, the processor can identify the level of wear on the ledge portion **234** of the outer retaining ring **230**. In some embodiments, if the area of the largest object is greater than a predetermined value, then no alarm is reported by the processor; and if the area of the largest object is less than a predetermined value, then an alarm is reported. In some embodiments, preventive maintenance is performed to replace the outer retaining ring **230** with a new one when the alarm is reported.

[0042] Reference is made to FIGS. 4 and 5. FIG. 5 is a cross-sectional view taken along line 5 of FIG. 4. The polish head **200** further includes a rail **265** in the carrier head **210**. The rail **265** is a circular rail and is disposed in a peripheral region of the polish head **200** and above the gap G between the inner retaining ring **220** and the outer retaining ring **230**. The rail **265** extends substantially along the gap G. The image capturing device **250** is coupled to the rail **265** and is movable along the rail **265** and thus movable along the gap G. In some embodiments, the image capturing device **250** includes a light source **252** and a light receiver **254**. The light source **252** and the light receiver **254** are disposed on a bottom surface of a bracket **270** and face the gap G. The bracket **270** is held by the rail **265**. In some embodiments, a plurality of bearing rollers **272** are disposed between a bottom portion of the rail **265** and the bracket **270**. The bracket **270** and the image capturing device **250** are supported by the bearing roller **272**. The bracket **270** is connected

to and driven by a motor, such that the bracket **270** and the image capturing device **250** can be moved along the rail **265**. In some embodiments, a plurality of guiding rollers **274** are disposed between the bracket **270** and sidewalls of the rail **265**, such that the movement of the bracket **270** can be more stable.

[0043] In some other embodiments, as shown in FIG. **6**, a plurality of image capturing device **250** are arranged along the gap G between the inner retaining ring **220** and the outer retaining ring **230** of the polish head **200**. Each of the image capturing devices **250** is not moveable and is configured to capture images at its local location. In some embodiments, the image capturing device **250** are arranged at regular intervals.

[0044] Reference is now made to FIGS. **1**, **2**, and FIG. **7**. FIG. **7** is a flowchart of a method for operating the CMP system **100** of FIG. **1**. In step S**12**, a CMP process is performed on a wafer **10** using the CMP system **100**. During the CMP process, slurry **20** is supplied to the polish pad **120**. For example, the slurry **20** is supplied by the slurry dispenser **150**, and at least one of the nozzles **154** drops the slurry **20** on the polish pad **120**. The platen **110** is driven by a motor to rotate the polish pad **120** about a rotation axis. The wafer **10** is secured upside-down in the polish head **200**, surrounded by the inner retaining ring **220**, and under the membrane **240**. The polish head **200** is lowered to the polish pad **120** and presses the wafer **10** against the polish pad **120**. In some embodiments, after the polish head **200** is lowered to the polish pad **120**, the membrane **240** of the polish pad **120** is pressurized to push the wafer **10** towards the polish pad **120**.

[0045] The polish head **200** is driven by a drive shaft to rotate, and to oscillate. In some embodiments, the oscillation path of the polish head **200** is along a radial direction of the polish pad **120**. As the polish head **200** rotates and sweeps across the polish pad **120**, the outer retaining ring **230** retains the inner retaining ring **220** in a horizontal position, and the inner retaining ring **220** in turn retains the wafer **10** in a horizontal position. The slurry **20** flows through the indented slots **260** (see FIG. **4**) of the outer retaining ring **230** and the indented slots **262** (see FIG. **4**) of the inner retaining ring **220** to the wafer **10**.

[0046] The conditioner **140** is pressed against the polish pad **120** and made to rotate and oscillate, for maintaining an even surface on the polish pad **120**.

[0047] In step S**14**, images of the gap between the outer retaining ring **230** and the inner retaining ring **220** are captured using the image capturing device **250**. In some embodiments, the image capturing device **250** is moved along the gap between the inner retaining ring **220** and the outer retaining ring **230** after single CMP process of the wafer **10** is completed, and then captures images of the gap. In some embodiments, the image capturing device **250** captures images of the gap between the inner retaining ring **220** and the outer retaining ring **230** at regular intervals as it moves along the gap.

[0048] In some other embodiments, as shown in FIG. **6**, a plurality of image capturing device **250** are arranged inside the gap between the inner retaining ring **220** and the outer retaining ring **230** of the polish head **200**. The image capturing devices **250** are not moveable and in step S**14**, the image capturing devices **250** capture images at their local location.

[0049] Reference is made to FIG. **5**. In some embodiments, during each image capturing operation, the light source **252** of the image capturing device **250** is turned on to lighten the gap G between the inner retaining ring **220** and the outer retaining ring **230**, and the light receiver **254** of the image capturing device **250** captures the light reflected from the inner sidewall **236** of the wall portion **232** of the outer retaining ring **230**, the outer sidewall **222** of the inner retaining ring **220**, and/or the top surface **238** of the ledge portion **234**. In some embodiments, the light source **252** is continuously turned on during plural capturing operations; in some other embodiments, the light source **252** is a pulsed light source and is turned on during each capturing operation and is turned off after each capturing operation.

[0050] Reference is made to FIGS. **1** and **7**. In step S**16**, the images captured by the image capturing device **250** are analyzed to identify any possible defect. The possible defect may include

the contaminant residue in the gap between the inner retaining ring **220** and the outer retaining ring **230** and/or on the top surface of the ledge portion of the outer retaining ring **230**, and/or wear on the outer retaining ring **230** and/or the inner retaining ring **220**. If any defect is detected, an alarm is reported and a cleaning process and/or preventive maintenance are/is performed in response to the alarm to remove the defect.

[0051] In some embodiments, the steps **S14** and **S16** may be taken after polishing each wafer, or at the end of the entire chemical mechanical polishing process. In other words, steps **S14** and **S16** may be taken at the end of each cycle of step **S12**. In some other embodiments of the disclosure, steps **S14** and **S16** can be taken after a series of cycles of steps **12** is repeated multiple times.

[0052] Some embodiments of the present disclosure provide a polish head having an image capturing device disposed between the inner retaining ring and the outer retaining ring. The image capturing device is configured to capture images of the gap between the inner retaining ring and the outer retaining ring. The captured images can be analyzed to identify any possible defect.

[0053] According to some embodiments of the disclosure, a polish head of a chemical mechanical polishing system. The polish head includes a carrier head, a membrane mounted to the carrier head, an inner retaining ring mounted to the carrier head and surrounding the membrane, an outer retaining ring mounted to the carrier head and surrounding the inner retaining ring, and an image capturing device. The outer retaining ring is spaced apart from the inner retaining ring. The image capturing device is mounted to the carrier head and between the inner retaining ring and the outer retaining ring.

[0054] According to some embodiments of the disclosure, a method includes performing, using a chemical mechanical polishing (CMP) system, a CMP process on a wafer; and after performing the CMP process, capturing an image of a gap between an inner retaining ring and an outer retaining ring of a polish head of the CMP system.

[0055] According to some embodiments of the disclosure, a method includes picking up a wafer using a polish head having an inner retaining ring and an outer retaining ring, in which the outer retaining ring has a wall portion and a ledge portion extending from the wall portion toward the inner retaining ring. The wafer is polished. After polishing the wafer, an image of a top surface of the ledge portion of the outer retaining ring is captured.

[0056] The foregoing outlines features of several embodiments so that those skilled in the art may better understand the aspects of the present disclosure. Those skilled in the art should appreciate that they may readily use the present disclosure as a basis for designing or modifying other processes and structures for carrying out the same purposes and/or achieving the same advantages of the embodiments introduced herein. Those skilled in the art should also realize that such equivalent constructions do not depart from the spirit and scope of the present disclosure, and that they may make various changes, substitutions, and alterations herein without departing from the spirit and scope of the present disclosure.

Claims

1. A polish head of a chemical mechanical polishing (CMP) system, the polish head comprising: a carrier head; a membrane mounted to the carrier head; an inner retaining ring mounted to the carrier head and surrounding the membrane; an outer retaining ring mounted to the carrier head and surrounding the inner retaining ring, wherein the outer retaining ring is spaced apart from the inner retaining ring; and an image capturing device mounted to the carrier head and between the inner retaining ring and the outer retaining ring.
2. The polish head of claim 1, wherein the image capturing device comprises a photodiode.
3. The polish head of claim 1, wherein the image capturing device comprises an indium gallium arsenide photodiode.
4. The polish head of claim 1, further comprising a rail in the carrier head, wherein the image

capturing device is coupled to the rail.

5. The polish head of claim 4, further comprising: a bracket, the image capturing device being on a bottom surface of the bracket; and a plurality of bearing rollers between the rail and the bracket.

6. The polish head of claim 1, wherein the inner retaining ring has a slot in a bottom surface of the inner retaining ring, the outer retaining ring has a slot in a bottom surface of the outer retaining ring, and the slot of the inner retaining ring is substantially aligned with the slot of the outer retaining ring.

7. The polish head of claim 6, wherein a width of the slot of the outer retaining ring is greater than a width of the slot of the inner retaining ring.

8. The polish head of claim 1, wherein the inner retaining ring is softer than the outer retaining ring in hardness.

9. The polish head of claim 1, wherein the outer retaining ring has a wall portion and a ledge portion extending from the wall portion toward the inner retaining ring.

10. The polish head of claim 9, wherein at least a portion of the image capturing device is directly above the ledge portion.

11. A polish head of a chemical mechanical polishing (CMP) system, the polish head comprising: a carrier head; a membrane mounted to the carrier head; an inner retaining ring mounted to the carrier head and surrounding the membrane; an outer retaining ring mounted to the carrier head and surrounding the inner retaining ring; and an image capturing device movable along a circular rail between the inner retaining ring and the outer retaining ring.

12. The polish head of claim 11, wherein the outer retaining ring comprises a ledge portion extending toward the inner retaining ring, and wherein the image capturing device is vertically above the ledge portion of the outer retaining ring.

13. The polish head of claim 12, wherein the image capturing device is configured to capture an image of the ledge portion of the outer retaining ring.

14. The polish head of claim 11, wherein the image capturing device comprises a photodiode.

15. The polish head of claim 11, wherein the inner retaining ring is softer than the outer retaining ring in hardness.

16. A polish head of a chemical mechanical polishing (CMP) system, the polish head comprising: a carrier head; a membrane mounted to the carrier head; an inner retaining ring mounted to the carrier head and surrounding the membrane; an outer retaining ring mounted to the carrier head and surrounding the inner retaining ring, wherein the outer retaining ring comprises a ledge portion extending toward the inner retaining ring; and an image capturing device between the inner retaining ring and the outer retaining ring, wherein the image capturing device is configured to capture an image of the ledge portion of the outer retaining ring.

17. The polish head of claim 16, wherein the image capturing device is movable along a rail between the inner retaining ring and the outer retaining ring.

18. The polish head of claim 17, wherein the rail has a circular shape.

19. The polish head of claim 16, wherein the image capturing device comprises a photodiode.

20. The polish head of claim 16, wherein the inner retaining ring is softer than the outer retaining ring in hardness.
