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(54) **POLISHING PAD WITH ENDPOINT WINDOW AND SYSTEMS AND METHODS USING THE SAME**

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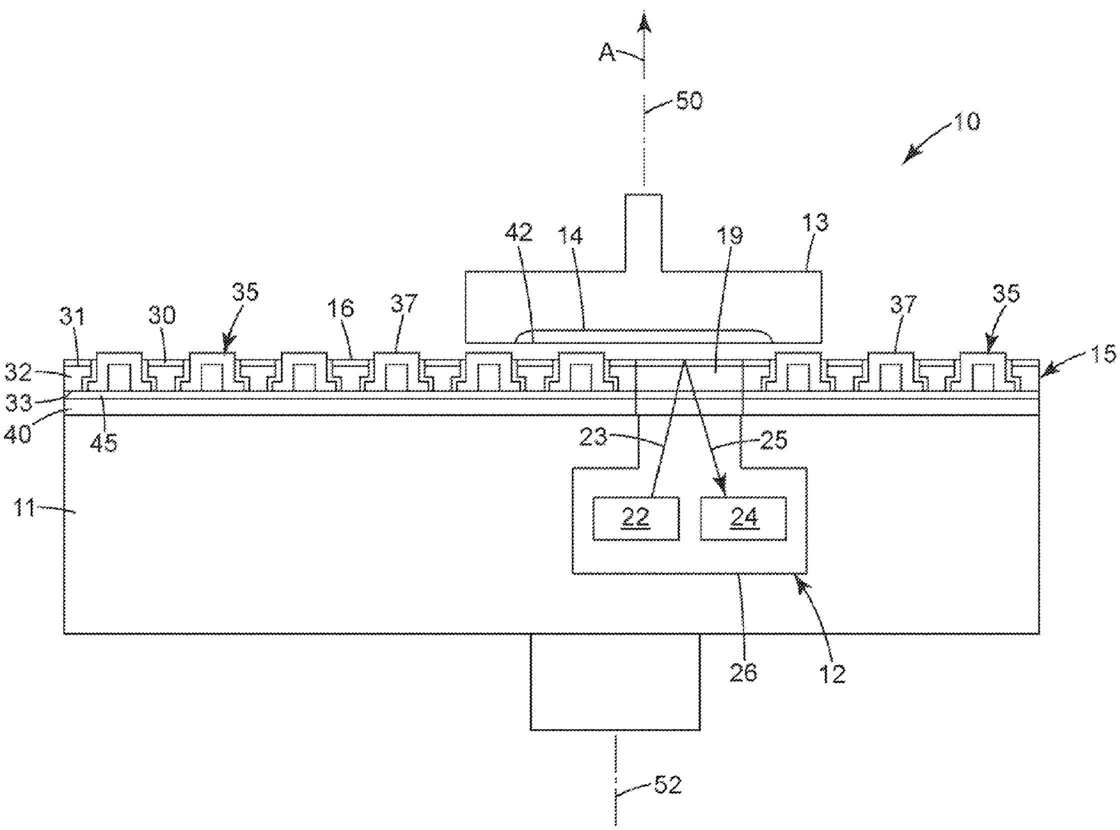
(57) **ABSTRACT**

A polishing pad including a path therethrough to transmit a signal for in situ monitoring of an endpoint in a polishing operation. In one embodiment, the polishing pad includes a polishing composition distribution layer on a first side of a guide plate and a support layer on an opposed second side of a guide plate. The guide plate retains a plurality of polishing elements that extend along a first direction substantially normal to a plane including the polishing pad and through the polishing composition distribution layer. The polishing pad includes an optical path along the first direction and through a thickness of the pad.



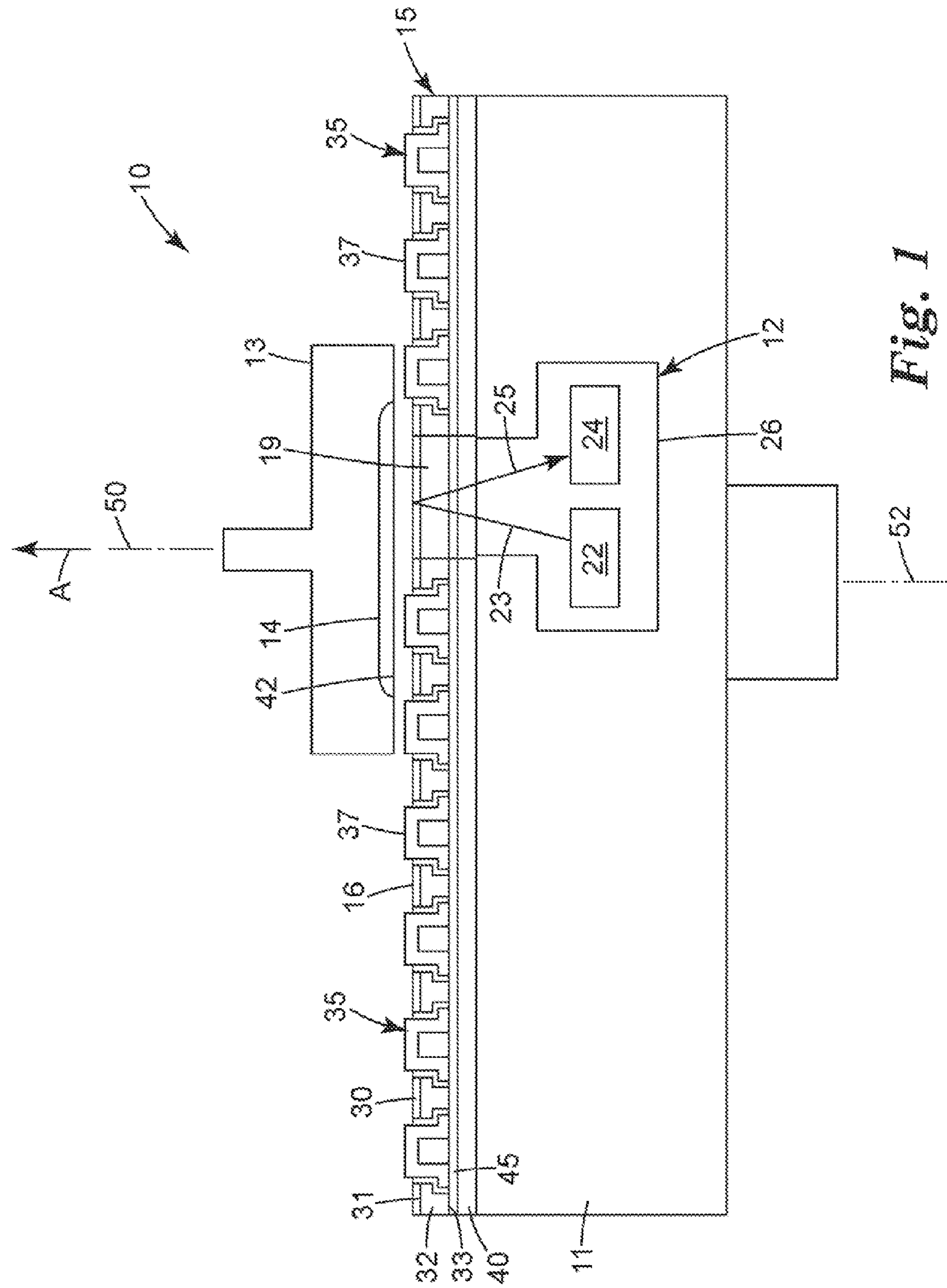

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Fig. 1

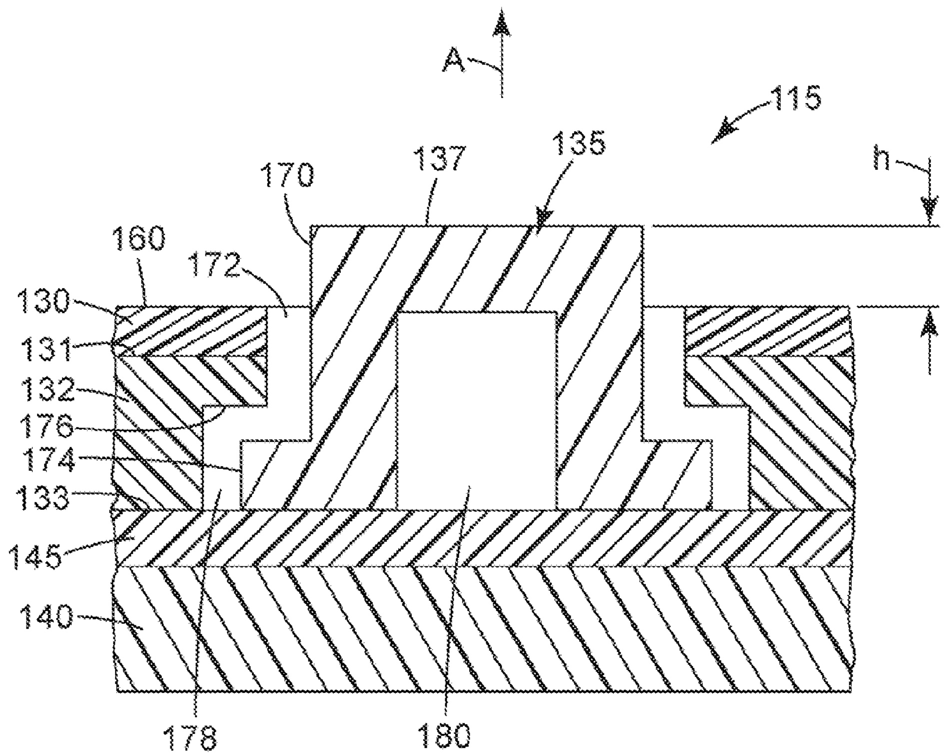
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Fig. 2

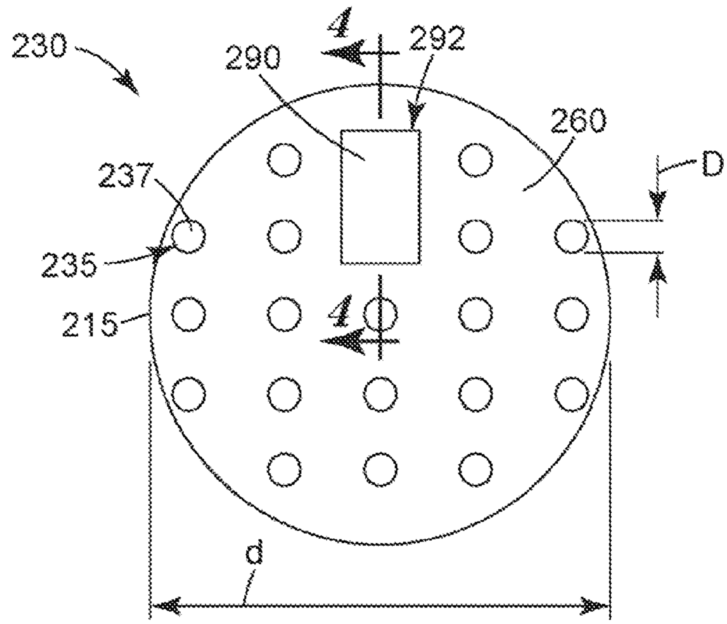
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Fig. 3

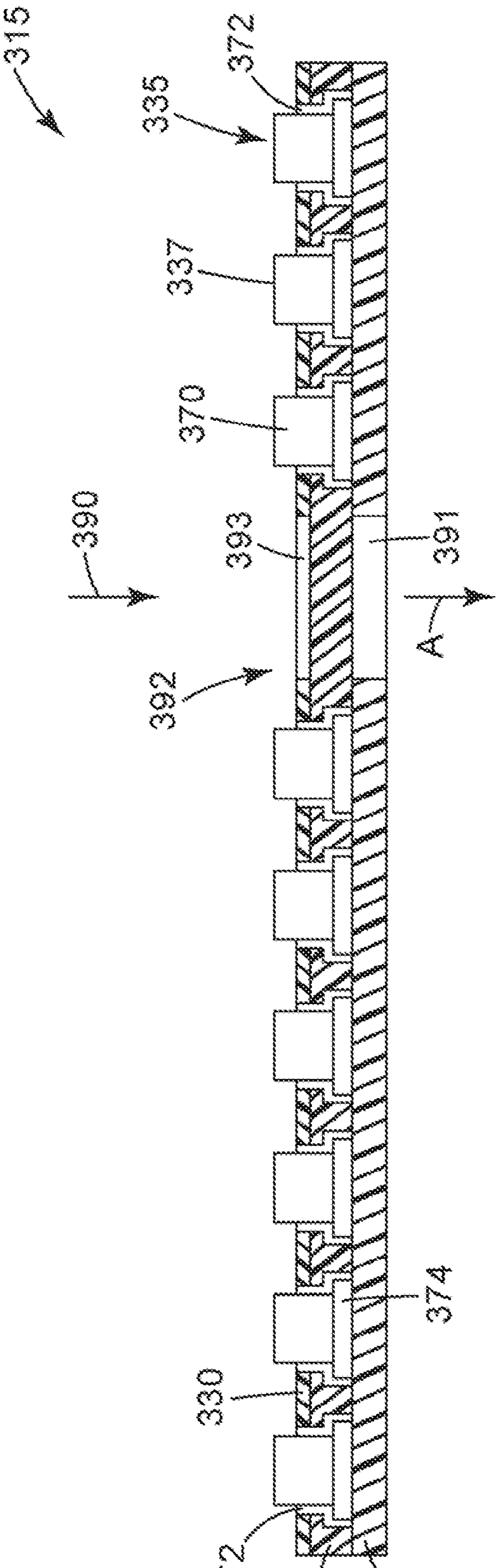


Fig. 4

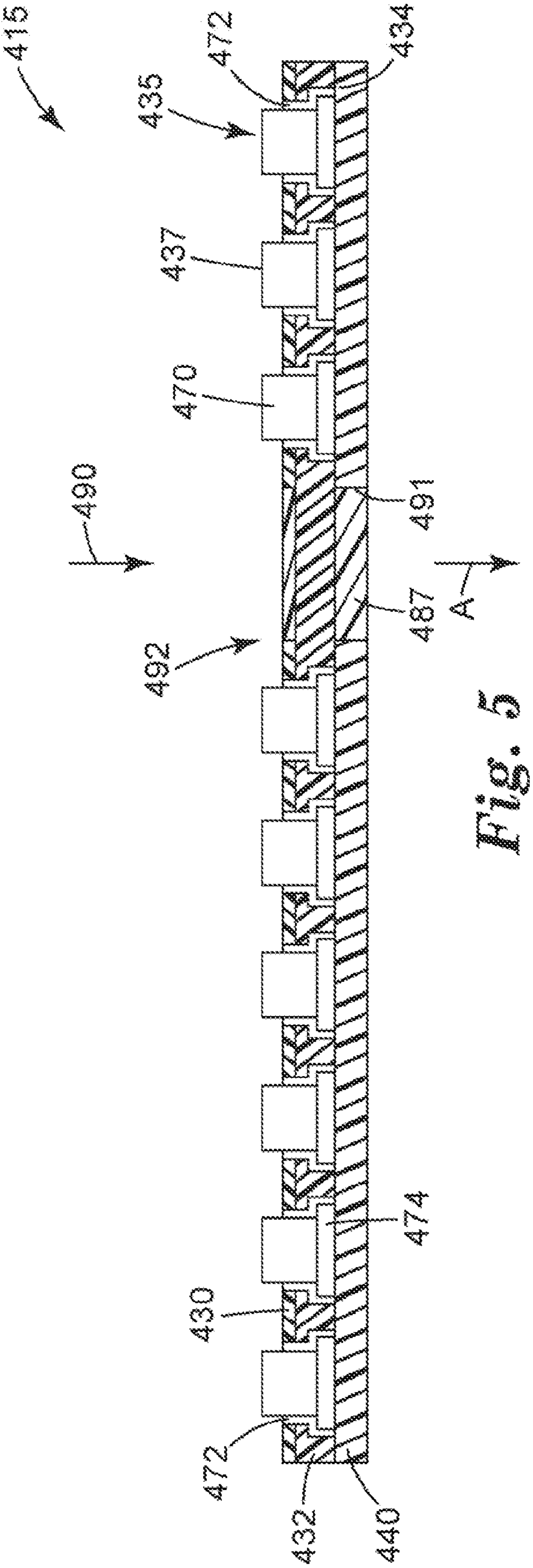


Fig. 5

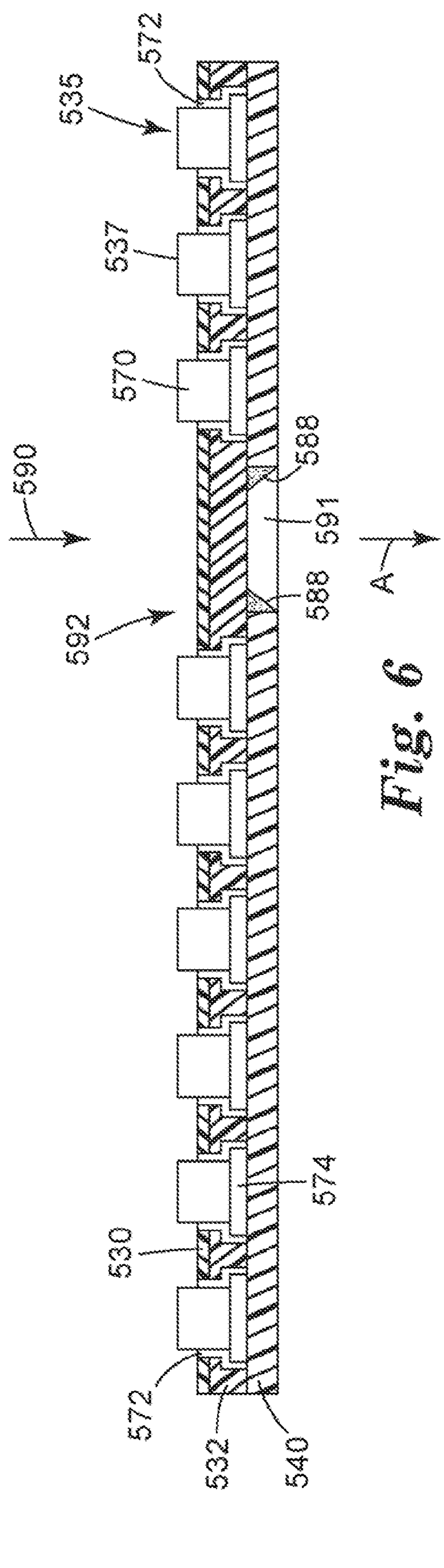


Fig. 6

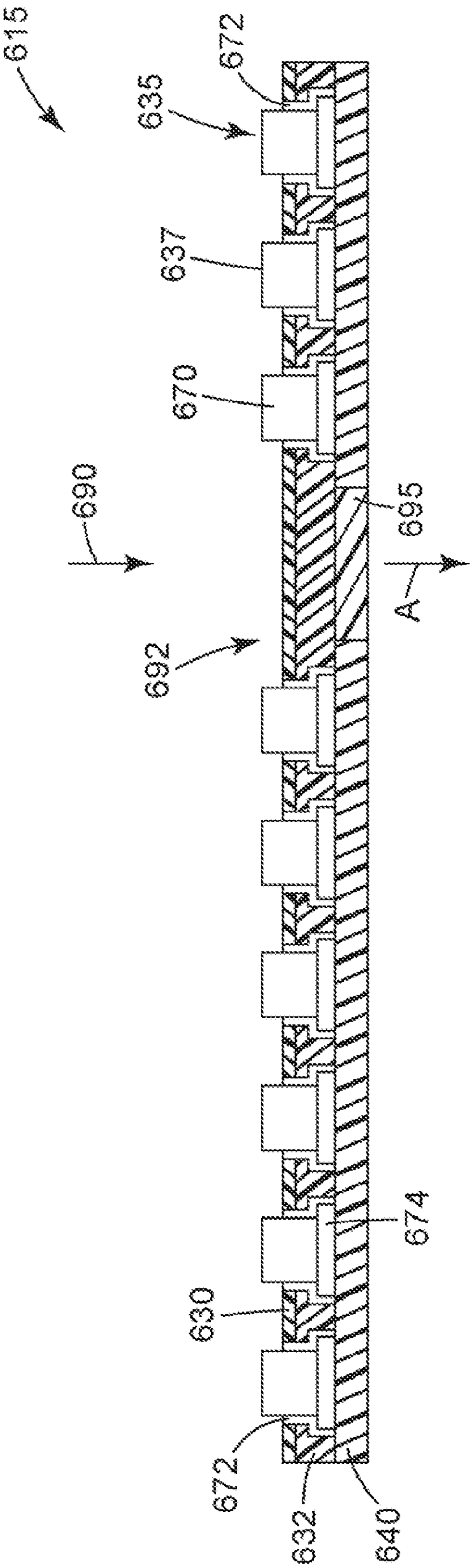
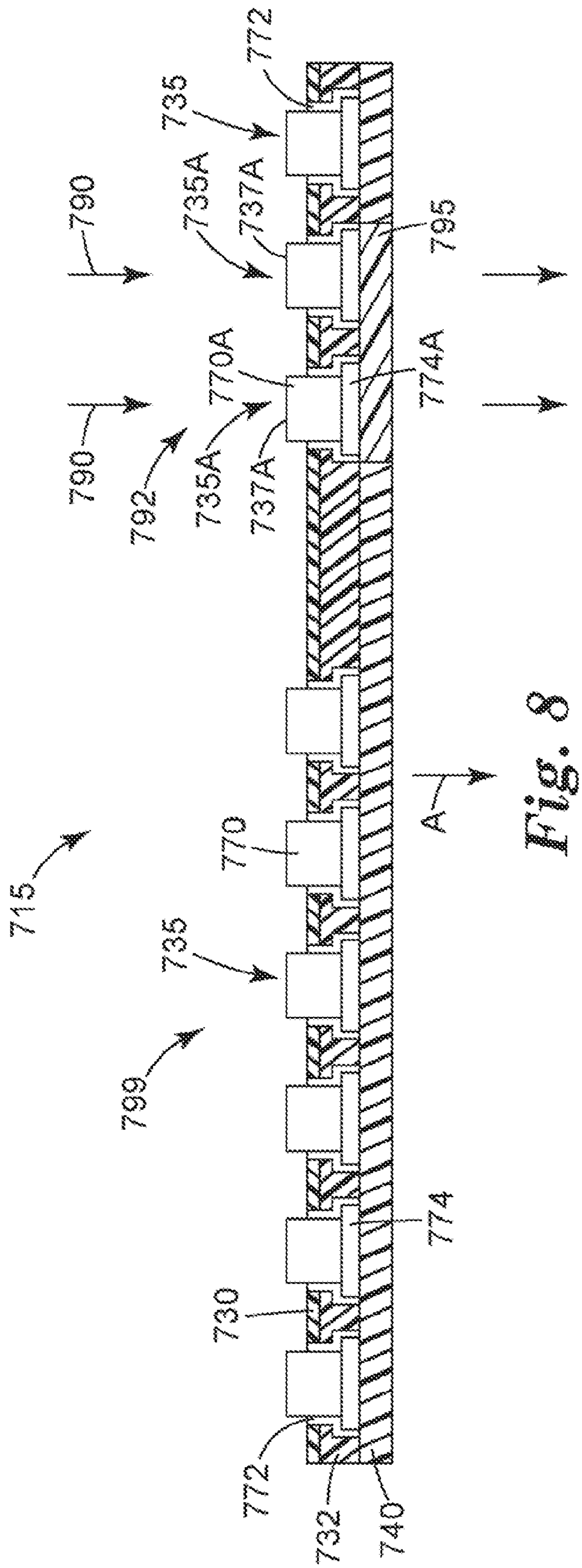


Fig. 7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772
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740

Fig. 8

POLISHING PAD WITH ENDPOINT WINDOW AND SYSTEMS AND METHODS USING THE SAME

TECHNICAL FIELD

[0001] The present disclosure relates to polishing pads with projecting polishing elements and a path through the thickness of the pad that makes possible the transmission of a monitoring signal for in situ determination of an endpoint in a polishing process.

BACKGROUND

[0002] During the manufacture of semiconductor integrated circuits, silicon wafers are iteratively processed through a series of deposition and etching cycles to form overlying material layers and structures. A polishing technique called chemical mechanical planarization (CMP) may be used to remove surface irregularities remaining after the deposition and etching steps, such as bumps, areas of unequal elevation, troughs, and trenches. In a chemical mechanical planarization process a substrate is pressed against and rotated with respect to a polishing pad in the presence of a polishing composition with abrasive and/or etching chemistry, typically a slurry.

[0003] During the planarization process, it is desirable to detect when the desired surface planarity or layer thickness has been reached and/or when an underlying layer has been exposed to determine when to stop polishing. For example, a deposited material can be removed from the substrate to a predetermined level and then the polishing process stopped via endpoint detection, a timed process or some other physical or chemical technique. In one endpoint detection technique, an optical monitoring system can be used for in situ measuring of the uniformity of a layer on a substrate. The optical monitoring system can include a radiation source that directs a beam of energy toward the substrate during polishing, a detector that measures the radiation reflected from the substrate, and a computer that analyzes a signal from the detector and calculates whether the endpoint has been detected.

[0004] In some chemical mechanical polishing systems, a light beam is directed toward the substrate through an open aperture in a polishing surface of the polishing pad, or through a transparent window member placed in the aperture in the polishing surface.

SUMMARY

[0005] In general, the present disclosure is directed to a polishing pad including a path therethrough to transmit a signal for in situ monitoring of an endpoint in a polishing operation.

[0006] In some embodiments, the path has a minimal impact on the polishing zone of the polishing pad (the surfaces of the polishing pad in contact with and/or responsible for abrading the substrate). The polishing zone is free of large apertures, transparent windows or other areas that can cause inconsistent polishing, pooling of polishing composition, or fouling with polishing composition. Transmission of the monitoring signal with minimal impact on the polishing zone can provide consistently accurate transmission of the monitoring signal without substantially compromising polishing performance.

[0007] In some embodiments, since the path does not require removal of material from the polishing zone, compared to conventional designs the transmission function of the path is more effectively decoupled from the polishing function of the pad. This decoupling can provide improved polishing and signal monitoring performance.

[0008] In some embodiments, the polishing pad described in this disclosure provides some or all of the following advantages. For example, in some embodiments, an aperture and/or a transparent member is provided in a support layer of the pad, away from the polishing zone. Placing the aperture/transparent member away from the polishing zone can prevent a polishing composition from entering the aperture, which reduces aperture fouling and abrasion of the transparent member. Placing the aperture/transparent member away from the polishing zone keeps the polishing composition away from the underside of the polishing pad and away from adhesives that can be used to hold the transparent member in position, which can extend the service life of the pad and the adhesive.

[0009] Since the transparent member does not come into contact with the polishing composition, the material from which the transparent member is made can be selected to more effectively transmit the monitoring signal without substantial regard to its resistance to wear from repeated exposure to the polishing composition. Since the transparent member does not wear prematurely from repeated exposure to polishing composition, the transparent member can maintain more consistent signal transmission properties over the service life of the polishing pad.

[0010] In one embodiment, the present disclosure is directed to a polishing pad including a polishing composition distribution layer on a first side of a guide plate and a support layer on an opposed second side of a guide plate. The guide plate retains a plurality of polishing elements that extend along a first direction substantially normal to a plane including the polishing pad and through the polishing composition distribution layer. The polishing pad includes an optical path along the first direction and through a thickness of the pad for transmitting a signal for in situ monitoring of an endpoint in a polishing operation.

[0011] In another embodiment, the present disclosure is directed to a polishing pad, including a polishing composition distribution layer on a first major surface of a transparent guide plate. The guide plate retains a plurality of polishing elements that extend along a first direction substantially normal to a plane including the polishing pad and through the polishing composition distribution layer. A first region in the polishing composition distribution layer is free of polishing elements. A support layer resides on the second major surface of the guide plate, and the support layer includes a transparent region underlying the first region.

[0012] In another embodiment, the disclosure is directed to a polishing pad including a polishing composition distribution layer with a plurality of polishing elements. The polishing elements extend upwardly through the polishing composition distribution layer. The polishing composition distribution layer includes a first region with at least one transparent polishing element. A support layer with a transparent region underlies the first region.

[0013] In yet another embodiment, the present disclosure is directed to a chemical mechanical polishing system including a platen and a polishing pad on the platen. The polishing pad includes a polishing composition distribution layer on a first major surface of a guide plate, wherein the guide plate retains a plurality of polishing elements that extend through the polishing composition distribution layer, and a support layer on a second major surface of the guide plate. The system further includes a means for transmitting a monitoring signal through the polishing pad; and a monitoring system to monitor a polishing operation, wherein the monitoring system emits a monitoring signal through the means for transmitting to a detector.

[0014] In yet another embodiment, the present disclosure is directed to a method including providing a chemical mechanical polishing apparatus with a monitoring system. The monitoring system emits a monitoring signal for monitoring a polishing operation and a detector for detecting the monitoring signal. The method further includes providing a polishing pad including a polishing composition distribution layer with a plurality of polishing elements that extend through the polishing composition distribution layer, and a support layer underlying the polishing composition distribution layer. The method further includes transmitting the monitoring signal from the source to the detector through a path in the polishing pad, wherein the path includes a transparent region in the support layer and a first region in the polishing composition distribution layer at least partially aligned with the transparent region. The first region includes one of a region free of polishing elements, or a region with at least one transparent polishing element.

[0015] The details of one or more embodiments of the invention are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the invention will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF DRAWINGS

[0016] FIG. **1** is a schematic cross-sectional view of a chemical mechanical polishing (CMP) apparatus utilizing the polishing pads described herein.

[0017] FIG. **2** is a schematic, cross-sectional view of a portion of a polishing pad including a polishing element.

[0018] FIG. **3** is a schematic top view of a polishing pad with a region including an optical path.

[0019] FIG. **4** is a cross-sectional view of an embodiment of a polishing pad with an optical path including a first aperture in a polishing composition distribution layer at least partially overlying a second aperture in a support layer.

[0020] FIG. **5** is a cross-sectional view of the polishing pad of FIG. **4**, wherein the optical path includes a transparent plug in the second aperture.

[0021] FIG. **6** is a cross-sectional view of the polishing pad of FIG. **4**, wherein the aperture in the support layer is at least partially sealed with a layer of an adhesive.

[0022] FIG. **7** is a cross-sectional view of an embodiment of a polishing pad with an optical path including a first aperture in a polishing composition distribution layer at least partially overlying a transparent region in a support layer.

[0023] FIG. **8** is a cross-sectional view of an embodiment of a polishing pad with an optical path including a transparent polishing element at least partially overlying a transparent region in a support layer.

[0024] Like reference numerals in the drawings indicate like elements. The drawings herein as not to scale, and in the drawings the components of the polishing pads are sized to emphasize selected features.

DETAILED DESCRIPTION

[0025] As shown in FIG. **1**, a chemical mechanical polishing apparatus **10** includes a polishing pad **15** disposed on a platen **11**. The platen **11** includes an endpoint monitoring system **12**. The endpoint monitoring system **12** may vary widely depending on the intended application, and may include systems utilizing a wide variety of monitoring signals. Examples include single or multi-wavelength monitoring signals, systems utilizing reflectometry or interferometry. For example, the monitoring system **12** can include an optical sensor, an eddy current sensor, a capacitance sensor and the like.

[0026] In the embodiment shown in FIG. **1**, the endpoint monitoring system **12** is an optical system that includes a light source **22** (e.g., a laser, such as a red laser, a blue laser, or an infrared laser, or a light emitting diode, such as a red light emitting diode, a blue light emitting diode, or an infrared light emitting diode) and a light detector **24** (e.g., a photodetector). In this embodiment, the optical monitoring system **12** is housed in a recess **26** in platen **11**, although such an arrangement is not required.

[0027] The apparatus **10** also includes a polishing head **13** that holds a substrate **14** (e.g., a semiconductor wafer, optionally coated with one or more dielectric, conductive or semiconductive layers). The endpoint monitoring system **12** monitors polishing of substrate **14** via an optical path **19** traversing the thickness of the polishing pad **15**—i.e. along a direction A generally normal to a plane including the pad. The pad **15** includes a polishing composition distribution layer **30** on a first side **31** of a guide plate **32**. The guide plate **32** retains an arrangement of elongate polishing elements **35**, which project upwardly through the polishing composition distribution layer **30**. The polishing elements **35** can have a wide variety of shapes, but generally the elements **35** are elongate bodies with a longitudinal axis generally along direction A. The polishing pad **15** further includes a support layer **40** on a second side **33** of the guide plate **32**.

[0028] The optical path **19**, which is shown schematically in FIG. **1**, will be described in more detail below, and may include one or more apertures, material layers, and/or polishing elements **35** that are collectively substantially transparent to energy or fields in the range of wavelength(s) of interest utilized by the endpoint monitoring system **12**. In this application, the term transparent means that at least about 25% (e.g., at least about 35%, at least about 50%, at least about 60%, at least about 70%, at least about 80%, at least about 90%, at least about 95%) of energy at a wavelength of interest that enters the optical path **19** is transmitted through the polishing pad **15** along the path **19**.

[0029] In general, during use of apparatus **10** in a CMP process, a chemical polishing composition (e.g., a slurry containing one or more chemical agents and optionally abrasive particles) is applied to a surface **16** of the polishing composition distribution layer **30**. The chemical polishing composition is applied to the polishing pad **15** as platen **11**, polishing pad **15** and endpoint monitoring system **22** rotate about an axis **52**. The polishing head **13** is lowered so that a surface **42** of substrate **14** comes into contact with the tips **37** of the polishing elements **35**. While the polishing composition distribution layer **30** distributes the polishing composition on the substrate and the polishing elements **35**, the polishing head **13** and the substrate **14** are rotated about an axis **50** and cause the polishing tips **37** to translate laterally across the polishing pad **15** and remove material from the substrate **14**. The light source **22** directs a light beam **23** at the surface **42**, and the light detector **24** measures the light beam **25** that is reflected from substrate **42** (e.g., from surface **42** and/or the surface of one or more underlying layers in substrate **42**).

[0030] In the embodiment shown in FIG. **1**, the wavelength (s) of light in beam **23** and/or **25** can vary depending upon the property being detected. As an example, the wavelength(s) of interest can span the visible spectrum (e.g., from about 400 nm to about 800 nm). As another example, the wavelength(s) of interest can be within a certain portion of the visible spectrum (e.g., from about 400 nm to about 450 nm, from about 650 nm to about 800 nm). As an additional example, the wavelength(s) of interest may be outside the visible portion of the spectrum (e.g., ultraviolet (such as from about 300 nm to about 400 nm), infrared (such as from about 800 nm to about 1550 nm)).

[0031] The information collected by the detector **24** is processed to determine whether the polishing endpoint has been reached. For example, a computer (not shown in FIG. **1**) can receive the measured light intensity from the detector **24** and evaluate the resulting signal to determine the polishing endpoint (e.g., by detecting a sudden change in the reflectivity of substrate **42** that indicates the exposure of a new layer, by calculating the thickness removed from the outer layer (such as a transparent oxide layer) of substrate **42** using interferometric principles, and/or by monitoring the signal for predetermined endpoint criteria.

[0032] FIG. **2** shows a cross sectional view of an individual elongate polishing element **135** in a polishing pad **115**. In the embodiment shown in FIG. **2**, the polishing element **135** is retained by a guide plate **132** and projects upwardly through a polishing composition distribution layer **130**. The polishing element **135** includes a polishing tip **137**, which may make sliding or rolling contact with a substrate to be polished. For example, the polishing tip **137** may be a substantially flat surface or a rolling tip. Prior to the first use of the polishing pad in a polishing operation, the height h of the polishing tip **135** is at least about 0.25 mm to about 3.0 mm above the upper surface **160** of the polishing composition distribution layer **130**, and in some embodiments h may be 0.5 mm, 1.5 mm, 2.0 mm, 2.5 mm, 3.0 mm or more, depending on the polishing composition used and the material selected for the polishing element **135**.

[0033] The polishing element **135** includes an elongate main body **170** with a longitudinal axis generally along direction A. The elongate body **170** resides in a main bore **172**, which extends through the polishing composition distribution layer **130** and the guide plate **132**. The polishing element **135** further includes at least one flange **174** extending outward from the body **170**, which engages a shoulder **176** formed by an undercut region **178** in the main bore **172** in the guide plate **132**. In the embodiment shown in FIG. **2**, the polishing element **135** includes a core region **180**, although such an arrangement is not required.

[0034] In some embodiments, the polishing element **135** rests on a first major surface **133** of a support layer **140**, and may optionally be attached to the surface **133** by a layer of a preferably transparent adhesive (not shown in FIG. **2**), such as double sided tape or epoxy. Thus, the polishing elements **135** are free to independently move in a vertical direction along their longitudinal axis A, through the main bore **172** in the guide plate **132** and the polishing composition distribution layer **130**.

[0035] The cross-sectional shape of the elongate main body **170** of the polishing element **135** may vary widely depending on the intended application. For example, circular, triangular, and trapezoidal cross sectional shapes have been found to be useful. For example, the polishing pad **215** in FIG. **3** includes polishing elements **235** with a circular cross sectional shape, which provides a polishing element with a substantially cylindrical main body. The polishing tip **237** is also substantially circular in this embodiment, and has a diameter D of at least about 50 μm. In some embodiments, the diameter D of the polishing tip **237** is about 50 μm to about 20 mm, in some embodiments the diameter D is about 5 mm to about 15 mm, and in other embodiments the diameter D is about 12 mm to about 15 mm.

[0036] The polishing elements **235** may be arranged on a surface **260** of the polishing composition distribution layer **230** in a wide variety of patterns, depending on the intended application, and the patterns may be regular or irregular. The polishing elements **235** may cover substantially the entire surface **260**, or there may be regions **292** of the surface **260** that include no polishing elements **235**. In some embodiments, the polishing elements have an average density between about 30 and about 80 percent of the total area of the surface **260**, as determined by the diameter D of each polishing element **235** and the diameter d of the polishing pad **215**.

[0037] Referring again to FIG. **2**, the depth and spacing of the bores **172** throughout the guide plate **132** may be varied as necessary for a specific CMP process. The polishing elements **135** are each maintained in planar orientation with respect to one other and the guide plate **132**, and project above the surface of the polishing composition distribution layer **130**. The volume created by the polishing elements **135** above the guide plate **132** and the polishing composition distribution layer **130** provides room for distribution of a polishing composition on the surface **160** of the polishing composition distribution layer **130**. The polishing elements **135** protrude above the polishing composition distribution layer **130** by an amount that depends at least in part on the material characteristics of the polishing elements **135** and the desired flow of polishing composition (preferably a slurry) over the surface **160**.

[0038] The polishing elements **135** may be made of a wide variety of materials, including, for example, metals, ceramics, polymeric materials and combinations thereof. Suitable polymeric materials include polyurethanes, polyesters, polycarbonates, and acetals available under the trade designation DELRIN from E.I. DuPont de Nemours, Inc., Wilmington, Del. Any of these materials may be made transparent to the wavelength of interest in the endpoint monitoring system **12** (FIG. **1**). In other embodiments, any of these materials, whether transparent or not, may be made electrically and/or thermally conductive by including therein fillers such as, carbon, graphite, metals or combinations thereof. In other embodiments, electrically conductive polymers such as, for example, polyanilines (PANI) available under the trade designation ORMECOM from Ormecon Chemie, Ammersbek, Germany, may be used, with or without the electrically or thermally conductive fillers referred to above.

[0039] While the elongate body **170**, the polishing tip **137** and the core **180** of the polishing element **135** can be made of the same material, such an arrangement is not required, and these portions of the polishing element **135** can be the same or different materials as necessary for a particular application. For example, in some embodiments the core **180** and/or the body **170** can be made of conductive materials and separated by an insulating material. In some embodiments, as described in WO/2006/055720, incorporated herein by reference, the core **180** of the polishing element **135** can include sensors to detect pressure, conductivity, capacitance, eddy currents, and the like. In yet another embodiment, the body **170** of the polishing element **135**, which is made of a first material, can be encased in a second and different material to, for example, enable signal transmission through the optical element **135**. In this arrangement, the second material does not take part in polishing operations.

[0040] Referring again to FIG. **2**, in some embodiments the guide plate **132** can provide lateral support for the polishing elements **135** and allow the elements **135** to move independently along direction A. The guide plate **132** includes the polishing composition distribution layer **130** on its first side, preferably on its first major surface **131**, and a support layer **140** on its second side, preferably on its second major surface **133**. The guide plate may further include an optional liquid impermeable membrane layer **145** on its second major surface **133** to control leakage of liquid polishing compositions.

[0041] The guide plate **132** can be made of a wide variety of materials, but a non-conducting and liquid impermeable polymeric material is preferred, and polycarbonates have been found to be particularly useful. The polymeric material is preferably transparent to the wavelength of interest in the endpoint monitoring system **12** (FIG. **1**).

[0042] The polishing composition distribution layer **130** may also be made of a wide variety of polymeric materials, and polyurethanes, polyethylenes and combinations thereof are particularly useful. The polyurethanes and polyethylenes are preferably foamed to provide a positive pressure directed toward to substrate during polishing operations when the layer **130** is compressed. Foamed materials with open cells are preferred. In some embodiments, the layer **130** has between about 10 and about 90 percent porosity, and can optionally be fastened to the guide plate **132** by a layer of a preferably transparent adhesive, or a double sided tape (not shown in FIG. **2**). In an alternative embodiment, the polishing composition layer **130** is made of a hydrogel material, such as, for example a hydrophilic urethane, that can absorb water in a range of about 5 to about 60 percent by weight to provide a lubricious surface during polishing operations.

[0043] The polishing composition distribution layer **130** substantially uniformly distributes a polishing composition across the substrate surface, which provides more uniform polishing operations. The polishing composition distribution layer **130** may optionally include flow resistant elements such as baffles, grooves (not shown in FIG. **2**), or pores, to regulate the flow rate of the polishing composition during polishing operations. In some embodiments, the layer **130** can include various layers of different materials to achieve desired polishing composition flow rates at varying depths from the surface **160**. For example, a surface layer at the polishing surface **160** may have larger pores to increase the amount and rate of a slurry flow on the surface **160** while a lower layer adjacent the guide plate **132** has smaller pores to keep more slurry near the surface **160** layer and more precisely regulate slurry flow.

[0044] The support layer **140** may be made of a wide variety of materials, and is preferably fluid impermeable (although permeable materials may be used in combination with an optional membrane layer **145**). The support layer **140** can be incompressible, such as a rigid frame or a housing, but is preferably compressible to provide a positive pressure directed toward the polishing surface **160**. The support layer **140** is preferably made of a polymeric material, foamed polymers are preferred, and foamed materials with closed cells are particularly preferred. Polyurethanes have been found to be particularly useful. Suitable polyurethanes include, for example, those available under the trade designation PORON from Rogers Corp., Rogers, Conn., as well as those available under the trade designation PELLETHANE from Dow Chemical, Midland, Mich., particularly PELLETHANE 2102-65D. Other suitable materials include polyethylene terepthalates (PET), such as, for example biaxially oriented PET widely available under the trade designation MYLAR, as well as bonded rubber sheets available from Rubberite Cypress Sponge Rubber Products, Inc., Santa Ana, Calif., under the trade designation BONDTEX. The support layer **140** can optionally be fastened to the guide plate by a layer of adhesive, preferably a transparent adhesive, or a double sided tape.

[0045] Referring again to FIG. **3**, the polishing pad **215** includes a region **292** that provides a path **290** through the thickness of the pad **215** (e.g. generally normal to the surface **260** of the polishing pad). As discussed in detail below, the region **292** may be free of polishing elements **235**, or may include transparent polishing elements **235**.

[0046] In an embodiment illustrated in FIG. **4**, a polishing pad **315** includes a polishing composition distribution layer **330**, a guide plate **332**, and a support layer **340**. The polishing composition distribution layer **330** and the guide plate **332** are collectively substantially transparent to energy or fields in the range of wavelength(s) of interest utilized by the endpoint monitoring system **12** (FIG. **1**). In some embodiments, the polishing composition distribution layer **330** and/or the guide plate **332** can be made of a transparent polymeric material.

[0047] The guide plate **332** includes plurality of apertures **372** each retaining a polishing element **335**. Each polishing element **335** includes an elongate body **370**, a retaining flange **374**, and a polishing tip **337**.

[0048] In this embodiment a region **392** of the polishing pad **315** is free of polishing elements **335**. In the region **392** a path **390** through the thickness of the polishing pad **315** (substantially normal to a plane of a major surface of the polishing pad **315** and along direction A) includes an aperture **391** in the support layer **340**.

[0049] In any of the embodiments described in this application, the polishing composition distribution layer **330** may optionally include an aperture (See, for example, aperture **392** in FIG. **4**) that overlies and/or is substantially aligned with an aperture (e.g. **391** in FIG. **4**) in the support layer **340**.

[0050] In an embodiment illustrated in FIG. **5**, a polishing pad **415** includes a polishing composition distribution layer **430**, a guide plate **432**, and a support layer **440**. The polishing composition distribution layer **430** and the guide plate **432** are collectively substantially transparent to energy or fields in the range of wavelength(s) of interest utilized by the endpoint monitoring system **12** (FIG. **1**). In some embodiments, the polishing composition distribution layer **430** and/or the guide plate **432** can be made of a transparent polymeric material.

[0051] The guide plate **432** includes plurality of apertures **472** each retaining a polishing element **435**. Each polishing element **435** includes an elongate body **470**, a retaining flange **474**, and a polishing tip **437**.

[0052] In this embodiment a region **492** of the polishing pad **415** is free of polishing elements **435**. In the region **492** an optical path **490** through the thickness of the polishing pad **415** (substantially normal to a plane of a major surface of the polishing pad **415** and along direction A) includes an aperture **491** in the support layer **440**. In this embodiment the aperture **491** includes a transparent member (e.g. a plug) **487**. The transparent member **487** may be affixed to the second side of the guide plate **432**, preferably a second major surface **434** of the guide plate **432**, with any suitable transparent adhesive or adhesively backed tape. In some embodiments, a cure in place transparent adhesive may be used.

[0053] For example, the transparent member **487** can be formed of one or more polymeric materials, such as, a polyurethane or a halogenated polymer (e.g., polychlorotrifluoroethylene (PCTFE), perfluoroalkoxy (PFA), fluorinated ethylene propylene (FEP), or polytetra-fluoroethylene (PTFE)).

[0054] The transparent member **487** is substantially transparent to energy in the range of wavelength(s) of interest utilized by the endpoint detection apparatus **12** (FIG. **1**). In certain embodiments, at least about 25% (e.g., at least about 35%, at least about 50%, at least about 60%, at least about 70%, at least about 80%, at least about 90%, at least about 95%) of energy at a wavelength of interest that impinges upon the transparent member **487** is transmitted therethrough.

[0055] For example, the transparent member **487** can be made of a material with a refractive index of about 1.48 or less (e.g., about 1.45 or less, about 1.4 or less, about 1.35 or less, about the same as the refractive index of water), which can reduce reflections at interfaces along an optical path **490** and improve the signal to noise ratio of the endpoint detection apparatus. In some embodiments, the transparent member **487** can be formed of a highly optically isotropic polymer, which can help maintain the polarization of the interrogating energy beam from the endpoint detection apparatus.

[0056] In certain implementations, surfaces of the transparent member **487** can also optionally be roughened to improve adhesion to the guide plate **432**, or to alter the interference of light beams traveling through them.

[0057] In some embodiments, the polishing composition distribution layer **430** may include an aperture (not shown in FIG. **4**) that overlies the aperture **491** in the support layer **440**.

[0058] In an embodiment illustrated in FIG. **6**, a polishing pad **515** includes a polishing composition distribution layer **530**, a guide plate **532**, and a support layer **540**. The polishing composition distribution layer **530** and the guide plate **532** are collectively substantially transparent to energy or fields in the range of wavelength(s) of interest utilized by the endpoint monitoring system **12** (FIG. **1**). In some embodiments, the polishing composition distribution layer **530** and/or the guide plate **532** can be made of a transparent polymeric material.

[0059] The guide plate **532** includes plurality of apertures **572** each retaining a polishing element **535**. Each polishing element **535** includes an elongate body **570**, a retaining flange **574**, and a polishing tip **537**.

[0060] In this embodiment a region **592** of the polishing pad **515** is free of polishing elements **535**. In the region **592** an optical path **590** through the thickness of the polishing pad **515** (substantially normal to a plane of the major surface of the polishing pad **515** and along direction A) includes an aperture **591** in the support layer **540**. It can be useful, particularly if the support layer **540** is made of a foamed or other porous material, to at least partially seal the foam in the walls of the aperture **591** with an adhesive **588**. The adhesive **588** preferably seals at interfaces between the guide plate **532** and the support layer **540** within the aperture **591**, as well as along the exposed walls of the support layer **540** in the aperture **591**. A substantially continuous bead of adhesive **588** can substantially eliminate migration of liquid polishing compositions that can interfere with the operation of the endpoint apparatus. Any suitable adhesive **588** may be used, and rapidly curable, moisture resistant adhesives are preferred, and transparent adhesives of these types are particularly preferred.

[0061] In some embodiments, the polishing composition distribution layer **530** may include an aperture (not shown in FIG. **5**) that overlies the aperture **591** in the support layer **540**.

[0062] In yet another embodiment illustrated in FIG. **7**, a polishing pad **615** includes a polishing composition distribution layer **630**, a guide plate **632**, and a support layer **640**. The polishing composition distribution layer **630** and the guide plate **632** are collectively substantially transparent to energy or fields in the range of wavelength(s) of interest utilized by the endpoint monitoring system **12** (FIG. **1**). In some embodiments, the polishing composition distribution layer **630** and/or the guide plate **632** can be made of a transparent polymeric material.

[0063] The guide plate **632** includes plurality of apertures **672**, each retaining a polishing element **635**. Each polishing element **635** includes an elongate body **670**, a retaining flange **674**, and a polishing tip **637**.

[0064] In this embodiment a region **692** of the polishing pad **615** is free of polishing elements **635**. The region **692** overlies and is at least partially aligned with a region **695** of the support layer **640**. The region **695**, which may be made of a material that is the same or different from the remainder of the support layer **640**, is substantially transparent to energy in the range of wavelength(s) of interest utilized by the endpoint detection apparatus **12** (FIG. **1**). In certain embodiments, at least about 25% (e.g., at least about 35%, at least about 50%, at least about 60%, at least about 70%, at least about 80%, at least about 90%, at least about 95%) of energy at a wavelength of interest that impinges upon the region **695** is transmitted therethrough.

[0065] For example, the region **695** may be transparent, or may be made transparent by applying heat and/or pressure to the material, or a transparent material may be cast in place in an aperture suitably positioned in the support layer **640** (i.e. underlying the region **692**). In an alternative embodiment, the entire support layer **640** may be made of a material that is or may be made transparent to energy in the range of wavelength(s) of interest utilized by the endpoint detection apparatus. Preferred transparent materials for the layer **640** and the region **695** include, for example, polyurethanes.

[0066] In some embodiments, the polishing composition distribution layer **630** may include an aperture (not shown in FIG. **6**) that overlies the region **695** in the support layer **640**.

[0067] In yet another embodiment illustrated in FIG. **8**, a polishing pad **715** includes a polishing composition distribution layer **730** and a guide plate **732**, each of which may optionally be made of transparent materials, as well as a support layer **740**. In a first region **799** of the polishing pad **715**, the guide plate **732** includes plurality of apertures **772**, each retaining a polishing element **735**. Each polishing element **735** includes an elongate body **770**, a retaining flange **774**, and a polishing tip **737**.

[0068] A second region **792** of the polishing pad **715**, different from the first region **799**, includes at least one transparent polishing element **735**A. In the region **792** an optical path **790** through the thickness of the polishing pad **715** (substantially normal to a plane of the major surface of the polishing pad **715** and along direction A) traverses at least one transparent polishing element **735**A, which overlies and is at least partially aligned with a region **795** of the support layer **740**. The region **795**, which may be made of a material that is the same or different from the remainder of the support layer **740**, is substantially transparent to energy in the range of wavelength(s) of interest utilized by the endpoint detection apparatus **12** (FIG. **1**). In certain embodiments, at least about 25% (e.g., at least about 35%, at least about 50%, at least about 60%, at least about 70%, at least about 80%, at least about 90%, at least about 95%) of energy at a wavelength of interest that impinges upon the region **695** is transmitted therethrough.

[0069] For example, the region **795** may be made transparent by applying heat and/or pressure to the material, or a transparent material may be cast in place in an aperture in the support layer **740**. In an alternative embodiment, the entire support layer **740** may be made of a material that is or can be made transparent to energy in the range of wavelength(s) of interest utilized by the endpoint detection apparatus. Preferred transparent materials for the layer **740** and the region **795** include, for example, polyurethanes.

[0070] In the embodiment shown in FIG. **8**, the size of the region **792** that includes the transparent polishing elements **735**A may vary widely depending on the intended application. The polishing pad **715** may include a single transparent polishing element **735**A, a relatively small number of transparent polishing elements **735**A, or only transparent polishing elements **735**A. Polishing pads **715** with only transparent polishing elements are generally less expensive to manufacture, and for at least this reason are preferred over pads including mixtures of transparent and opaque polishing elements.

[0071] Referring again to FIG. **2**, the polishing pads **115** described herein are relatively inexpensive to manufacture. Suitable manufacturing processes are described in U.S. Patent Application No. 60/926,244, which is incorporated herein by reference in its entirety. A brief discussion of an exemplary manufacturing process is described herein, which is not intended to be limiting. For example, the guide plate **132** may be made by laminating both sides of a sheet of a suitable relatively rigid polymeric material, such as a polycarbonate, with an adhesive. The adhesive layers may be used to bond an appropriate polishing composition distribution layer **130**, and then an array of apertures may then be created (for example, by drilling) in the sheet to form the bores **170** and the undercut regions **174**.

[0072] The polishing elements **135** are preferably injection molded, and may then be applied to the drilled sheet. Since the polishing elements **135** include flanges **174**, gravity pulls the elements **135** into position in the bores **170** in the guide plate **132**.

[0073] A support layer **140** may then be laminated onto the resulting construction to form a completed polishing pad.

[0074] The present disclosure is further directed to a method in which a monitoring signal emitted by a monitoring system in a chemical mechanical polishing apparatus is transmitted through a thickness of a polishing pad to a detector to monitor an endpoint in a polishing operation. The polishing pads described in FIGS. **2**-**8** above include a transparent region in the support layer and a first region in the polishing composition distribution layer at least partially aligned with the transparent region. The first region in the polishing composition distribution layer includes one of: a region free of polishing elements or a region with at least one transparent polishing element. The monitoring signal can be transmitted through the thickness of the polishing pad via the first region in the polishing composition distribution layer and the transparent region in the support layer.

[0075] The polishing pads described in the present disclosure will now be illustrated with reference to the following non-limiting example.

EXAMPLE

[0076] Optical endpoint signal tests were performed using the polishing pads described herein, and the results were compared to commercially available polishing pads available from Applied Materials, Inc., Santa Clara, Calif., under the trade designation Mirra.

[0077] 200 mm silicon wafers were deposited with 5000 Å silicon dioxide followed by 250 Å tantalum nitride (TaN) and a thin copper layer followed by 15,000 Å electroplated copper films.

[0078] During processing, polish pressure of 2 pounds per square inch (Psi) (about 13,800 N/m2) was applied to the wafers and the pad table was rotated at 100 rpm. Commercially available copper removal slurry from Paulmark International, Inc., Taipei, Taiwan, was supplied at 150 ml/min.

[0079] Initial signal intensity was high due to high reflectivity of the copper surface, but as the copper surface was removed to expose barrier material, in this case, TaN, surface reflectivity was reduced and a drop in signal intensity was observed. This decrease in reflectivity was used to determine the end of the copper polish process.

[0080] The polishing pads were tested for signal integrity and signal magnitude, and the signal intensity change observed on the tool at location **1** was about 10-12 units for the conventional pad. The polishing pads described herein in FIGS. **4** and **8** each registered a signal intensity change at a level of about 8-12 units at location **1** on the tool. These results indicate that the optical paths in the presently described polishing pads have signal transmission characteristics that are similar to the transmission characteristics of the commercially available polishing pads

[0081] Various embodiments of the invention have been described. These and other embodiments are within the scope of the following claims.

1. A polishing pad comprising a polishing composition distribution layer on a first side of a guide plate and a support layer on an opposed second side of a guide plate, wherein the guide plate retains a plurality of polishing elements that extend along a first direction substantially normal to a plane including the polishing pad and through the polishing composition distribution layer, wherein the polishing pad comprises an optical path along the first direction and through a thickness of the pad for transmitting a signal for in situ monitoring of an endpoint in a polishing operation.

2. The polishing pad of claim **1**, wherein the optical path comprises a first region in the polishing composition distribution layer free of polishing elements and a transparent region in the support layer, wherein the transparent region is substantially aligned along the first direction with the first region.

3. The polishing pad of claim **2**, wherein the transparent region comprises an aperture in the support layer.

4. The polishing pad of claim **3**, wherein the polishing composition distribution layer comprises an aperture overlying the aperture in the support layer.

5. The polishing pad of claim **3**, further comprising a transparent member in the aperture in the support layer, wherein the transparent member is adjacent to the second side of the guide plate.

6. The polishing pad of claim **5**, further comprising a layer of adhesive between the transparent member and a major surface of the guide plate.

7. The polishing pad of claim **3**, further comprising an adhesive on at least a portion of an exposed wall of the aperture in the support layer.

8. The polishing pad of claim **3**, further comprising an adhesive at an interface between the support layer and the guide plate.

9. The polishing pad of claim **1**, wherein the guide plate is transparent.

10. The polishing pad of claim **2**, wherein the transparent region in the support layer comprises a transparent polymer.

11. The polishing pad of claim **2**, wherein the entire support layer comprises a transparent polymer.

12. The polishing pad of claim **1**, wherein the guide plate comprises a transparent polymer.

13. The polishing pad of claim **1**, wherein the polishing elements comprise elongate cylinders, and wherein a longitudinal axis of the cylinders is along the first direction.

14. The polishing pad of claim **13**, wherein the polishing elements comprise a flange, and wherein the flange engages the guide plate.

15. The polishing pad of claim **1**, wherein the polishing elements have a hollow body.

16. The polishing pad of claim **1**, wherein the guide plate comprises an array of apertures, and wherein at least a portion of the apertures comprise a main bore and an undercut region, and wherein the undercut region forms a shoulder that retains a flange on a polishing element.

17. A polishing pad comprising

a polishing composition distribution layer comprising a plurality of polishing elements, wherein the polishing elements extend upwardly through the polishing composition distribution layer, and wherein the polishing composition distribution layer comprises a first region comprising at least one transparent polishing element; and

a support layer comprising a transparent region underlying the first region.

18. The polishing pad of claim **17**, wherein the guide plate is transparent.

19. The polishing pad of claim **17**, wherein the transparent region in the support layer comprises a transparent polymer.

20. The polishing pad of claim **17**, wherein the entire support layer comprises a transparent polymer.

21. A chemical mechanical polishing system, comprising:

a platen;

the polishing pad of claim **17** on the platen; and

a monitoring system to monitor a polishing operation, wherein the monitoring system emits a monitoring signal to a detector through the first region and the transparent region.

22. A method comprising polishing a workpiece with the polishing pads of claim **1** or **17**.

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