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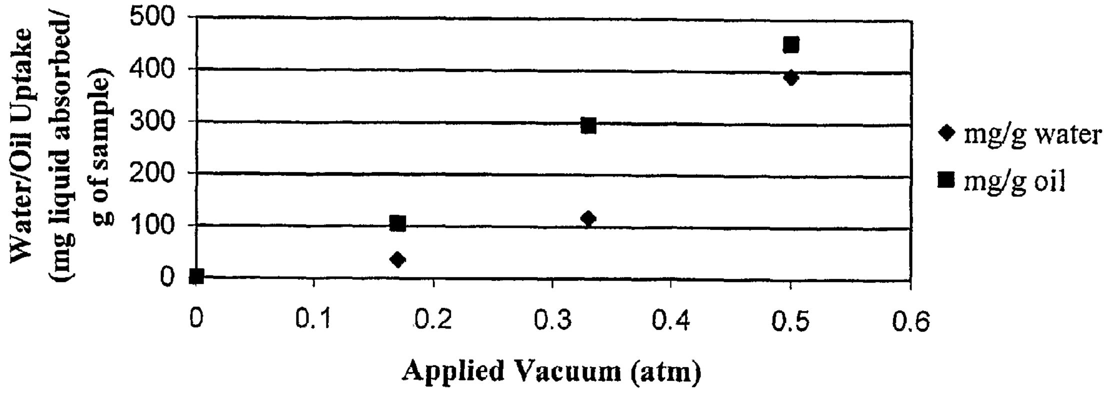
**(54) Title:** CMP POROUS PAD WITH COMPONENT-FILLED PORES



**(57) Abstract:** The invention provides a polishing pad comprising a polymeric material having pores and a component that is disposed within the pores, as well as a method of polishing a workpiece with the aforesaid polishing pad, and a method for producing the aforesaid polishing pad.

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# CMP POROUS PAD WITH COMPONENT-FILLED PORES

## FIELD OF THE INVENTION

**[0001]** This invention pertains to a polishing pad suitable for use in chemical-mechanical polishing systems.

## BACKGROUND OF THE INVENTION

**[0002]** Chemical-mechanical polishing ("CMP") processes are used in the manufacturing of microelectronic devices to form flat surfaces on semiconductor wafers, field emission displays, and many other microelectronic workpieces. For example, the manufacture of semiconductor devices generally involves the formation of various process layers, selective removal or patterning of portions of those layers, and deposition of yet additional process layers above the surface of a semiconducting workpiece to form a semiconductor wafer. The process layers can include, by way of example, insulation layers, gate oxide layers, conductive layers, and layers of metal or glass, etc. It is generally desirable in certain steps of the wafer process that the uppermost surface of the process layers be planar, i.e., flat, for the deposition of subsequent layers. CMP is used to planarize process layers wherein a deposited material, such as a conductive or insulating material, is polished to planarize the wafer for subsequent process steps.

**[0003]** In a typical CMP process, a wafer is mounted upside down on a carrier in a CMP tool. A force pushes the carrier and the wafer downward toward a polishing pad. The carrier and the wafer are rotated above the rotating polishing pad on the CMP tool's polishing table. A polishing composition (also referred to as a polishing slurry) generally is introduced between the rotating wafer and the rotating polishing pad during the polishing process. The polishing composition typically contains a chemical that interacts with or dissolves portions of the uppermost wafer layer(s) and an abrasive material that physically removes portions of the layer(s). The wafer and the polishing pad can be rotated in the same direction or in opposite directions, whichever is desirable for the particular polishing process being carried out. The carrier also can oscillate across the polishing pad on the polishing table.

**[0004]** Polishing pads used in chemical-mechanical polishing processes are manufactured using both soft and rigid pad materials, which include polymer-impregnated fabrics, microporous films, cellular polymer foams, non-porous polymer sheets, and sintered thermoplastic particles. A pad containing a polyurethane resin impregnated into a polyester non-woven fabric is illustrative of a polymer-impregnated fabric polishing pad. Microporous polishing pads include microporous urethane films coated onto a base material, which is often an impregnated fabric pad. These polishing pads are closed cell, porous films. Cellular polymer foam polishing pads contain a closed cell structure that is randomly and uniformly distributed in all three dimensions. Non-porous polymer sheet polishing pads include a polishing surface made from solid polymer sheets, which have no intrinsic ability to transport slurry particles (see, for example, U.S. Patent 5,489,233). These solid polishing pads are externally modified with large and/or small grooves that are cut into the surface of the pad purportedly to provide channels for the passage of slurry during chemical-mechanical polishing. Such a non-porous polymer polishing pad is disclosed in U.S. Patent 6,203,407, wherein the polishing surface of the polishing pad comprises grooves that are oriented in a way that purportedly improves selectivity in the chemical-mechanical polishing. Sintered polishing pads comprising a porous open-celled structure can be prepared from thermoplastic polymer resins. For example, U.S. Patents 6,062,968 and 6,126,532 disclose polishing pads with open-celled, microporous substrates, produced by sintering thermoplastic resins.

**[0005]** Although several of the above-described polishing pads are suitable for their intended purpose, a need remains for other polishing pads that provide effective planarization, particularly in workpieces polished by chemical-mechanical polishing. There also is a need for polishing pads with improved polishing uniformity that minimize the number of defects, such as edge-on effects and dishing, produced during workpiece polishing.

**[0006]** The invention provides such a polishing pad. These and other advantages of the invention, as well as additional inventive features, will be apparent from the description of the invention provided herein.

## BRIEF SUMMARY OF THE INVENTION

**[0007]** The invention provides a polishing pad comprising a polymeric material having pores and a component disposed within the pores. The invention further provides a method of polishing a workpiece comprising (i) providing a workpiece to be polished, (ii) contacting the workpiece with a chemical-mechanical polishing system comprising the polishing pad of the invention, and (iii) abrading at least a portion of the surface of the workpiece with the polishing system to polish the workpiece. The invention also provides a method for producing the polishing pad comprising (i) providing a porous polymeric material having gas-filled pores, (ii) subjecting said material to a pressure differential, (iii) contacting at least one surface of the material with a medium comprising the component, (iv) allowing the medium to permeate at least a portion of the pores, and (v) forming the polymeric material comprising component-filled pores into a polishing pad.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0008]** FIG. 1 is a graph of water and silicon oil uptake into a pad with closed-cell pores versus soak time at a fixed applied vacuum of 0.67 atm.

**[0009]** FIG. 2 is a graph of water and silicon oil uptake into a pad with closed-cell pores versus applied vacuum at a fixed soak time of 2 minutes.

**[0010]** FIG. 3 is a graph of the applied vacuum versus bulk modulus for a pad with closed-cell pores after a fixed soak time of 2 minutes in water.

## DETAILED DESCRIPTION OF THE INVENTION

**[0011]** The invention provides a chemical-mechanical polishing pad comprising a polymeric material and a component selected from a liquid, a solid, or a mixture thereof, wherein the polymeric material has pores and the component is disposed within the pores. The term "pore" describes void spaces within the polymeric material matrix that are at least partially bounded solely by the polymeric material. In addition, the term "pore" describes both open-celled pores and closed-celled pores.

**[0012]** The polishing pad of the invention comprises, consists essentially of, or consists of the polymeric material and the component. The polymeric material can be any suitable polymeric material, typically a thermoplastic polymer or a thermoset polymer. Preferably the polymeric material is a thermoplastic polymer or a thermoset polymer selected from the group consisting of polyurethanes, polyolefins, polyvinylalcohols, polyvinylacetates, polycarbonates, polyacrylic acids, polyacrylamides, polyethylenes, polypropylenes, nylons, fluorocarbons, polyesters, polyethers, polyamides, polyimides, polytetrafluoroethylenes, polyetheretherketones, copolymers thereof, and mixtures thereof. Preferably, the thermoplastic polymer or the thermoset polymer is selected from the group consisting of polyurethanes and polyolefins.

**[0013]** The component can be any suitable liquid, solid, or mixture thereof. The component can be any suitable liquid, such as water, an organic solvent (e.g., a nonaromatic hydrocarbon, an aromatic hydrocarbon such as m-pyrol mesitylene, an alcohol, an organic acid, a halogen-containing hydrocarbon, a halogen-containing organic acid, a thiol, or an ether), an inorganic acid (e.g., hydrochloric acid, sulfuric acid, phosphoric acid, or nitric acid), silicon oil, or any combination or mixture thereof. For example, the liquid can be a solution comprising a solvent and a solute. The solvent can be any suitable liquid or mixture of liquids, such as those described above, and the solute can be any substance (i.e., solid, liquid, or gas) that is at least partially soluble in or miscible with the solvent in a range of temperatures defined by the melting point and the boiling point of the solvent. For example, the solution can comprise at least two solution phases at a temperature of 40 °C or less, or the solution can comprise one solution phase at a temperature of 40 °C or more. In addition, the solution can be a thermoreversible gel. The thermoreversible gel has the property of forming a gel within a certain temperature range (i.e., the gelation temperature range), and the thermoreversible gel can be a liquid or a solid when the temperature is outside the gelation temperature range. The thermoreversible gel can comprise, for example, polyethylene and xylene.

**[0014]** The component also can be any suitable solid or mixture of solids. The solid can be a particle, and the solid particle can have any suitable average particle diameter. For example, the average particle diameter can be 5000 μm or less (e.g., 2500 μm or less, 1000 μm or less, or 500 μm or less). Alternatively, the average particle diameter can be 1 μm or more (e.g., 100 μm or more, 250 μm or more, or 500 μm or more). In particular, the solid can consist of nanoparticles having a largest diameter of 1 μm or less (e.g., 0.8 μm or less, 0.5 μm or less, or 0.1 μm or less). In addition, the solid can be conductive. The solid also can be an abrasive particle, such as a metal oxide (e.g., alumina, silica, titania, ceria, zirconia, germania, magnesia, co-formed products thereof, and combinations thereof).

**[0015]** The component also can be any suitable mixture of liquid and solid. For example, the component can be a slurry, a dispersion, a colloid, or a suspension.

**[0016]** The polishing pad of the invention comprises a polymeric material having pores. The pores can comprise open-celled pores, closed-celled pores, or a combination thereof.

For example, the pores can comprise 70% or more (e.g., 80% or more or 90% or more) open-celled pores. The pores can also comprise 70% or more (e.g., 80% or more or 90% or more) closed-celled pores. The pores can have any suitable void volume (i.e., the volume of the pores). For example, the void volume can be 75% or less (e.g., 65% or less, 55% or less, or 45% or less).

**[0017]** The component is disposed within the pores and can be distributed in any suitable arrangement within the pores. The component can be disposed in 70% or more (e.g., 80% or more, 85% or more, 90% or more, or 95% or more) of the void volume of the pores in the polymeric material. In another embodiment, the polishing pad of the invention can comprise a component uniformly distributed within the pores in the polymeric material.

**[0018]** Alternatively, the polishing pad of the invention can comprise a component distributed within the pores in a first region of the polishing pad. The polishing pad comprises a first surface, an opposing second surface, and a thickness between the surfaces. A first region of the polishing pad can be defined by the first surface of the polishing pad and by 50% or less (e.g., 40% or less, 20% or less, 10% or less, or 5% or less) of the thickness of the polishing pad. A second region of the polishing pad can be defined by the opposing second surface of the polishing pad and by 50% or less (e.g., 40% or less, 20% or less, 10% or less, or 5% or less) of the thickness of the polishing pad. The first region and the second region can comprise pores and can have any suitable volume. For example, the first region, the second region, or both can have a volume of 50 $cm^3$ or less (e.g., 40 $cm^3$ or less, 30 $cm^3$ or less, 20 $cm^3$ or less, 10 $cm^3$ or less, or 5 $cm^3$ or less). The component can be disposed within 70% or more (e.g., 80 % or more, 85% or more, 90% or more, or 95% or more) of the void volume of the pores in the first region, the second region, or both.

**[0019]** In another embodiment, the component can be disposed within 70% or more (e.g., 80 % or more, 85% or more, 90% or more, or 95% or more) of the void volume of the pores located within 1000 μm or less (e.g., 750 μm or less, 500 μm or less, 250 μm or less, or 100 μm or less) of the surface of the polishing pad.

**[0020]** The polishing pad of the invention can have any suitable pore density. For example, the pore density can be 10 pores/$cm^3$ or greater (e.g., 15 pores/$cm^3$ or greater, 20 pores/$cm^3$ or greater, or 25 pores/$cm^3$ or greater). The polishing pad of the invention can also have any suitable average pore diameter. For example, the average pore diameter can be 0.1 μm or more (e.g., 1 μm or more, 5 μm or more, 10 μm or more). Alternatively, the average pore diameter can be 5000 µm or less (e.g., 2500 µm or less, 1000 µm or less, or 500 µm or less).

**[0021]** The polishing pad of the invention can have any suitable density. For example, the density can be 1 g/cm$^3$ or less (e.g., 0.8 g/cm$^3$ or less or 0.5 g/cm$^3$ or less). Alternatively, the polishing pad of the invention can have a density that is 75% or less of the theoretical density of the polymeric material (e.g., 65% or less, 55% or less, or 45% or less).

**[0022]** The polishing pad of the invention can be used alone, or optionally can be mated to another polishing pad. When two polishing pads are mated, the polishing pad intended to contact the workpiece to be polished serves as the polishing layer, while the other polishing pad serves as the subpad. For example, the polishing pad of the invention can be a subpad that is mated to a conventional polishing pad having a polishing surface, wherein the conventional polishing pad serves as the polishing layer. Alternatively, the polishing pad of the invention can comprise a polishing surface, and serve as the polishing layer, and can be mated to a conventional polishing pad that serves as a subpad. Suitable polishing pads for use as the polishing layer in combination with a polishing pad of the invention include solid or porous polyurethane pads, many of which are well known in the art. Suitable subpads include polyurethane foam subpads, impregnated felt subpads, microporous polyurethane subpads, or sintered urethane subpads. The polishing layer and/or the subpad optionally comprises grooves, channels, hollow sections, windows, apertures, and the like. The subpad can be affixed to the polishing layer by any suitable means. For example, the polishing layer and subpad can be affixed through adhesives or can be attached via welding or similar technique. Typically, an intermediate backing layer such as a polyethyleneterephthalate film is disposed between the polishing layer and the subpad. When the polishing pad of the invention is mated to a conventional polishing pad, the composite polishing pad also is considered a polishing pad of the invention.

**[0023]** The polishing layer can be modified by buffing or conditioning, such as by moving the pad against an abrasive surface. The preferred abrasive surface for conditioning is a disk which is preferably metal and which is preferably embedded with diamonds of a size in the range of 1 µm to 0.5 mm. Optionally, conditioning can be conducted in the presence of a conditioning fluid, preferably a water-based fluid containing abrasive particles.

**[0024]** The polishing layer optionally further comprises grooves, channels, and/or perforations. Such features can facilitate the lateral transport of a polishing composition across the surface of the polishing layer. The grooves, channels, and/or perforations can be in any suitable pattern and can have any suitable depth and width. The polishing pad can have two or more different groove patterns, for example a combination of large grooves and small grooves as described in U.S. Patent 5,489,233. The grooves can be in the form of linear grooves, slanted grooves, concentric grooves, spiral or circular grooves, or XY crosshatch pattern, and can be continuous or non-continuous in connectivity.

**[0025]** The polishing pad of the invention optionally further comprises one or more apertures, transparent regions, or translucent regions (e.g., windows as described in U.S. Patent 5,893,796). The inclusion of such apertures or translucent regions (i.e., optically transmissive regions) is desirable when the polishing pad substrate is to be used in conjunction with an *in situ* CMP process monitoring technique. The aperture can have any suitable shape and may be used in combination with drainage channels for minimizing or eliminating excess polishing composition on the polishing surface. The optically transmissive region or window can be any suitable window, many of which are known in the art. For example, the optically transmissive region can comprise a glass or polymer-based plug that is inserted in an aperture of the polishing pad or may comprise the same polymeric material used in the remainder of the polishing pad. Typically, the optically transmissive regions have a light transmittance of 10% or more (e.g., 20% or more, or 30% or more) at one or more wavelengths between from 190 nm to 10,000 nm (e.g., from 190 nm to 3500 nm, from 200 nm to 1000 nm, or from 200 nm to 780 nm).

**[0026]** The optically transmissive region can have any suitable structure (e.g., crystallinity), density, and porosity. For example, the optically transmissive region can be solid or porous (e.g., microporous or nanoporous having an average pore size of less than 1 μm). Preferably, the optically transmissive region is solid or is nearly solid (e.g., has a void volume of 3% or less). The optically transmissive region optionally further comprises particles selected from polymer particles, inorganic particles, and combinations thereof. The optically transmissive region optionally contains pores.

**[0027]** The optically transmissive region optionally further comprises a dye, which enables the polishing pad material to selectively transmit light of a particular wavelength(s). The dye acts to filter out undesired wavelengths of light (e.g., background light) and thus improves the signal to noise ratio of detection. The optically transmissive region can comprise any suitable dye or may comprise a combination of dyes. Suitable dyes include polymethine dyes, di-and tri-arylmethine dyes, aza analogues of diarylmethine dyes, aza (18) annulene dyes, natural dyes, nitro dyes, nitroso dyes, azo dyes, anthraquinone dyes, sulfur dyes, and the like. Desirably, the transmission spectrum of the dye matches or overlaps with the wavelength of light used for *in situ* endpoint detection. For example, when the light source for the endpoint detection (EPD) system is a HeNe laser, which produces visible light having a wavelength of 633 nm, the dye preferably is a red dye, which is capable of transmitting light having a wavelength of 633 nm.

**[0028]** The polishing pad of the invention optionally contains particles, e.g., particles that are incorporated into the polymeric material. The particles can be abrasive particles, polymer particles, composite particles (e.g., encapsulated particles), organic particles, inorganic particles, clarifying particles, water-soluble particles, and mixtures thereof. The polymer particles, composite particles, organic particles, inorganic particles, clarifying particles, and water-soluble particles also may be abrasive, or may be non-abrasive, in nature.

**[0029]** The abrasive particles can be of any suitable material. For example, the abrasive particles can comprise a metal oxide, such as a metal oxide selected from the group consisting of alumina, silica, titania, ceria, zirconia, germania, magnesia, co-formed products thereof, and combinations thereof, or a silicon carbide, boron nitride, diamond, garnet, or ceramic abrasive material. The abrasive particles can be hybrids of metal oxides and ceramics or hybrids of inorganic and organic materials. The particles also can be polymer particles many of which are described in U.S. Patent 5,314,512, such as polystyrene particles, polymethylmethacrylate particles, liquid crystalline polymers (LCP), polyetheretherketones (PEEK's), particulate thermoplastic polymers (e.g., particulate thermoplastic polyurethane), particulate cross-linked polymers (e.g., particulate cross-linked polyurethane or polyepoxide), or a combination thereof. If the porous re-entrant material comprises a polymer resin, then the polymer particle desirably has a melting point that is higher than the melting point of the polymer resin of the porous foam. The composite particles can be any suitable particle containing a core and an outer coating. For example, the composite particles can contain a solid core (e.g., a metal oxide, metal, ceramic, or polymer) and a polymeric shell (e.g., polyurethane, nylon, or polyethylene). The clarifying particles can be phyllosilicates, (e.g., micas such as fluorinated micas, and clays such as talc, kaolinite, montmorillonite, hectorite), glass fibers, glass beads, diamond particles, carbon fibers, and the like.

**[0030]** The polishing pad of the invention can be prepared in any suitable manner. A preferred method for producing the polishing pad of the invention comprises: (i) providing a polymeric material comprising gas-filled pores, (ii) subjecting the polymeric material to a pressure differential, (iii) contacting at least one surface of the polymeric material with a medium comprising a component selected from a liquid, a solid, or a mixture thereof, (iv) allowing the medium comprising the component to permeate at least a portion of the pores of the polymeric material, and (v) forming the polymeric material comprising component-filled pores into a chemical-mechanical polishing pad.

**[0031]** The pressure differential is a pressure that is greater than or less than atmospheric pressure. For example, the pressure differential can be a pressure greater than 1 atm (e.g., 2 atm or more, 5 atm or more, 10 atm or more, or 20 atm or more). In another embodiment, the pressure differential can be a pressure less than 1 atm (e.g., 0.5 atm or less, 0.2 atm or less, 0.1 atm or less, 0.05 atm or less, or 0.005 atm or less). The polymeric material can be contacted with the medium comprising the component prior to subjecting the polymeric material to a pressure differential or after subjecting the polymeric material to a pressure differential.

**[0032]** The medium comprising the component is distributed in the pores of the polymeric material by the pressure differential. For example, the medium comprising the component can be uniformly distributed within the pores of the polymeric material by the pressure differential.

**[0033]** The polymeric material comprising pores containing the component (i.e., the component-filled pores) can be formed into a polishing pad, such as a polishing pad for use in chemical-mechanical polishing systems. The polishing pad can have any suitable shape (e.g., circular or linear). In addition, the polymeric material comprising component-filled pores can also be modified prior to or after being formed into a polishing pad. For example, the solvent can be dried to leave solute particles inside the pores, and the polymeric material comprising the component-filled pores can be compressed to form a polymeric sheet by molding at a temperature between the glass transition temperature (Tg) and the melting point temperature (Tm) of the polymeric material.

[0034] The polishing pad of the invention is particularly suited for use in conjunction with a chemical-mechanical polishing (CMP) apparatus. Typically, the apparatus comprises (a) a platen, which, when in use, is in motion and has a velocity that results from orbital, linear, or circular motion, (b) a polishing pad of the invention in contact with the platen and moving with the platen when in motion, and (c) a carrier that holds a workpiece to be polished by contacting and moving relative to the surface of the polishing pad intended to contact a workpiece to be polished. The polishing of the workpiece takes place by the workpiece being placed in contact with the polishing pad and then the polishing pad moving relative to the workpiece, typically with a polishing composition therebetween, so as to abrade at least a portion of the workpiece to polish the workpiece. The CMP apparatus can be any suitable CMP apparatus, many of which are known in the art. The polishing pad of the invention also can be used with linear polishing tools.

[0035] Suitable workpieces that can be polished with the polishing pad of the invention include memory storage devices, glass substrates, memory or rigid disks, metals (e.g., noble metals), magnetic heads, inter-layer dielectric (ILD) layers, polymeric films (e.g., organic polymers), low and high dielectric constant films, ferroelectrics, micro-electro-mechanical systems (MEMS), semiconductor wafers, field emission displays, and other microelectronic workpieces, especially microelectronic workpieces comprising insulating layers (e.g., metal oxide, silicon nitride, or low dielectric materials) and/or metal-containing layers (e.g., copper, tantalum, tungsten, aluminum, nickel, titanium, platinum, ruthenium, rhodium, iridium, silver, gold, alloys thereof, and mixtures thereof). The term "memory or rigid disk" refers to any magnetic disk, hard disk, rigid disk, or memory disk for retaining information in electromagnetic form. Memory or rigid disks typically have a surface that comprises nickel-phosphorus, but the surface can comprise any other suitable material. Suitable metal oxide insulating layers include, for example, alumina, silica, titania, ceria, zirconia, germania, magnesia, and combinations thereof. In addition, the workpiece can comprise, consist essentially of, or consist of any suitable metal composite. Suitable metal composites include, for example, metal nitrides (e.g., tantalum nitride, titanium nitride, and tungsten nitride), metal carbides (e.g., silicon carbide and tungsten carbide), metal silicides (e.g., tungsten silicide and titanium silicide), nickel-phosphorus, alumino-borosilicate, borosilicate glass, phosphosilicate glass (PSG), borophosphosilicate glass (BPSG), silicon/germanium alloys, and silicon/germanium/ carbon alloys. The workpiece also can comprise, consist essentially of, or consist of any suitable semiconductor base material. Suitable semiconductor base materials include monocrystalline silicon, polycrystalline silicon, amorphous silicon, silicon-on-insulator, and gallium arsenide. Preferably, the workpiece comprises a metal layer, more preferably a metal layer selected from the group consisting of copper, tungsten, tantalum, platinum, aluminum, and combinations thereof. Even more preferably, the metal layer comprises copper.

**[0036]** The polishing composition of the polishing system that can be used with the polishing pad of the invention typically comprises a liquid carrier (e.g., water) and optionally one or more additives selected from the group consisting of abrasives (e.g., alumina, silica, titania, ceria, zirconia, germania, magnesia, and combinations thereof), oxidizers (e.g., hydrogen peroxide and ammonium persulfate), corrosion inhibitors (e.g., benzotriazole), film-forming agents (e.g., polyacrylic acid and polystyrenesulfonic acid), complexing agents (e.g., mono-, di-, and poly-carboxylic acids, phosphonic acids, and sulfonic acids), pH adjustors (e.g., hydrochloric acid, sulfuric acid, phosphoric acid, sodium hydroxide, potassium hydroxide, and ammonium hydroxide), buffering agents (e.g., phosphate buffers, acetate buffers, and sulfate buffers), surfactants (e.g., nonionic surfactants), salts thereof, and combinations thereof. The selection of the components of the polishing composition depends in part on the type of workpiece being polished.

**[0037]** Desirably, the CMP apparatus further comprises an *in situ* polishing endpoint detection system, many of which are known in the art. Techniques for inspecting and monitoring the polishing process by analyzing light or other radiation reflected from a surface of the workpiece are known in the art. Such methods are described, for example, in U.S. Patent 5,196,353, U.S. Patent 5,433,651, U.S. Patent 5,609,511, U.S. Patent 5,643,046, U.S. Patent 5,658,183, U.S. Patent 5,730,642, U.S. Patent 5,838,447, U.S. Patent 5,872,633, U.S. Patent 5,893,796, U.S. Patent 5,949,927, and U.S. Patent 5,964,643. Desirably, the inspection or monitoring of the progress of the polishing process with respect to a workpiece being polished enables the determination of the polishing end-point, i.e., the determination of when to terminate the polishing process with respect to a particular workpiece.

**[0038]** The following examples further illustrate the invention but, of course, should not be construed as in any way limiting its scope.

## EXAMPLES 1-4

**[0039]** These examples demonstrate the uptake of a component into a polymeric foam, specifically carbon black into a polyolefin foam under various conditions. In each of these examples, a foam sample was placed in a medium containing the component and then subjected to a pressure of 0.5 atm in a vacuum chamber. The details of each of these examples are set forth in Table 1.

Table 1:

| Example | Foam Type | Impregnation Method | Component in Medium | Sample % wt. Gain |
|---|---|---|---|---|
| 1 | Closed-cell | Continuous vacuum, 22 °C for 1hr | 5% carbon black in m-pyrrol | 7.9 % |
| 2 | Closed-cell | Vacuum on/off, 50 °C, 1 hr | 0.8% carbon black in mesitylene | 4.4% |
| 3 | Open-cell | Vacuum on/off, 22 °C, 1 hr, one side of foam submerged in liquid medium | 0.8% carbon black in mesitylene | 22.9% |
| 4 | Open-cell | Vacuum on/off, 22 °C, 1 hr, foam completely submerged in liquid medium | 0.8% carbon black in mesitylene | 116 % |

**[0040]** The percent weight gained (i.e., sample % wt. gain) for each sample is set forth in Table 1 and indicates the extent of uptake of the carbon black into the pores of the foam. The results of these examples demonstrate that significant amount of a component, such as carbon black, can be distributed in the pores of a polymeric foam.

# CLAIMS

1. A chemical-mechanical polishing pad comprising a polymeric material and a component selected from a liquid, a solid, or a mixture thereof, wherein the polymeric material has pores and the component is disposed within the pores.

2. The polishing pad of claim 1, wherein the component is disposed within 70% or more of the pores located within 1000 µm or less of the surface of the polishing pad.

3. The polishing pad of claim 1, wherein the polymeric material is a thermoplastic polymer or a thermoset polymer.

4. The polishing pad of claim 3, wherein the thermoplastic polymer or the thermoset polymer is selected from the group consisting of polyurethanes, polyolefins, polyvinylalcohols, polyvinylacetates, polycarbonates, polyacrylic acids, polyacrylamides, polyethylenes, polypropylenes, nylons, fluorocarbons, polyesters, polyethers, polyamides, polyimides, polytetrafluoroethylenes, polyetheretherketones, copolymers thereof, and mixtures thereof.

5. The polishing pad of claim 4, wherein the thermoplastic polymer or the thermoset polymer is selected from the group consisting of polyurethanes and polyolefins.

6. The polishing pad of claim 1, wherein the component is a liquid.

7. The polishing pad of claim 6, wherein the liquid is a solution comprising a solvent and a solute.

8. The polishing pad of claim 7, wherein the solution comprises at least two solution phases.

9. The polishing pad of claim 8, wherein the solution comprises at least two solution phases at 40°C or less.

10. The polishing pad of claim 7, wherein the solution comprises one solution phase.

11. The polishing pad of claim 10, wherein the solution comprises one solution phase at 40°C or less.

12. The polishing pad of claim 7, wherein the solution is a thermoreversible gel.

13. The polishing pad of claim 12, wherein the thermoreversible gel comprises polyethylene and xylene.

14. The polishing pad of claim 1, wherein the component is a solid.

15. The polishing pad of claim 14, wherein the solid consists essentially of particles having a largest diameter of 1 µm or less.

16. The polishing pad of claim 14, wherein the solid is conductive.

17. The polishing pad of claim 14, wherein the solid consists essentially of abrasive particles.

18. The polishing pad of claim 17, wherein the abrasive particles comprise metal oxide selected from the group consisting of alumina, silica, titania, ceria, zirconia, germania, magnesia, co-formed products thereof, and combinations thereof.

19. The polishing pad of claim 1, wherein the polishing pad has a density of 2 g/cm$^3$ or less.

20. The polishing pad of claim 1, wherein the polishing pad has a void volume of 75% or less.

21. The polishing pad of claim 1, wherein the polishing pad has a pore density of 10 pores/cm$^3$ or greater.

22. The polishing pad of claim 1, wherein the average pore diameter is from 0.1 µm to 5000 µm.

23. The polishing pad of claim 1, wherein the polishing pad further comprises a polishing surface comprising grooves.

24. The polishing pad of claim 1, wherein the polishing pad further comprises an optically transmissive region.

25. The polishing pad of claim 24, wherein the optically transmissive region has a light transmission of at least 10% at one or more wavelengths between from 190 nm to 3500 nm.

26. The polishing pad of claim 1, wherein the polishing pad further comprises abrasive particles.

27. The polishing pad of claim 26, wherein the abrasive particles comprise metal oxide selected from the group consisting of alumina, silica, titania, ceria, zirconia, germania, magnesia, co-formed products thereof, and combinations thereof.

28. The polishing pad of claim 1, wherein the pores comprise 70% or more open-celled pores.

29. The polishing pad of claim 1, wherein the pores comprises 70% or more closed-celled pores.

30. The polishing pad of claim 1, wherein the polishing pad has a first surface, an opposing second surface, and a thickness between the first and second surfaces, wherein at least some of the pores are located within a first region of the polishing pad defined by the first surface and 10% or less of the thickness of the polishing pad, and wherein the component is disposed within 70% or more of the void volume of the pores within the first region.

31. The polishing pad of claim 30, wherein at least some of the pores are located within a second region of the polishing pad defined by the second surface and 10% or less of the thickness of the polishing pad and wherein the component is disposed within 70% or more of the void volume of the pores within the second region.

32. The polishing pad of claim 30, wherein the first region has a volume of 10 $cm^3$ or less.

33. The polishing pad of claim 31, wherein the second region has a volume of 10 $cm^3$ or less.

34. The method of polishing a substrate comprising

(i) providing a workpiece to be polished,

(ii) contacting the workpiece with a chemical-mechanical polishing system comprising the polishing pad of claim 1, and

(iii) abrading at least a portion of the surface of the workpiece with the polishing system to polish the workpiece.

35. The method of claim 34, wherein the polishing pad further comprises abrasive particles selected from the group consisting of abrasive particles, polymer particles, composite particles, water-soluble particles, and combinations thereof.

36. The method of claim 35, wherein the abrasive particles comprise metal oxide selected from the group consisting of alumina, silica, titania, ceria, zirconia, germania, magnesia, co-formed products thereof, and combinations thereof.

37. The method of claim 34, wherein the method further comprises detecting *in situ* a polishing endpoint.

38. A method for producing a chemical-mechanical polishing pad comprising:

(i) providing a polymeric material comprising gas-filled pores,

(ii) subjecting the polymeric material to a pressure differential,

(iii) contacting at least one surface of the polymeric material with a medium comprising a component selected from a liquid, a solid, or a mixture thereof,

(iv) allowing the medium comprising the component to permeate at least a portion of the pores of the polymeric material, and

(v) forming the polymeric material comprising component-filled pores into a chemical-mechanical polishing pad.

39. The method of claim 38, wherein the polymeric material is contacted with the medium after subjecting the porous polymeric material to a pressure differential.

40. The method of claim 38, wherein the polymeric material is contacted with the medium prior to subjecting the porous polymeric material to a pressure differential.

41. The method of claim 38, wherein the pressure differential is a pressure below atmospheric pressure.

42. The method of claim 38, wherein the pressure differential is a pressure above atmospheric pressure.

43. The method of claim 38, wherein the medium comprising the component is disposed within the pores by the pressure differential.

44. The method of claim 38, wherein the polymeric material comprising component-filled pores is compressed to form a polymeric sheet.

45. The method of claim 38, wherein the component is a liquid.

46. The method of claim 38, wherein the liquid is a solution comprising a solvent and a solute.

47. The method of claim 38, wherein the component is a solid.

48. The method of claim 47, wherein the solid consists essentially of particles having a largest diameter of 1 µm or less.

49. The method of claim 47, wherein the solid is conductive.

50. The method of claim 47, wherein the solid consists essentially of abrasive particles.

51. The method of claim 50, wherein the abrasive particles comprise metal oxide selected from the group consisting of alumina, silica, titania, ceria, zirconia, germania, magnesia, co-formed products thereof, and combinations thereof.

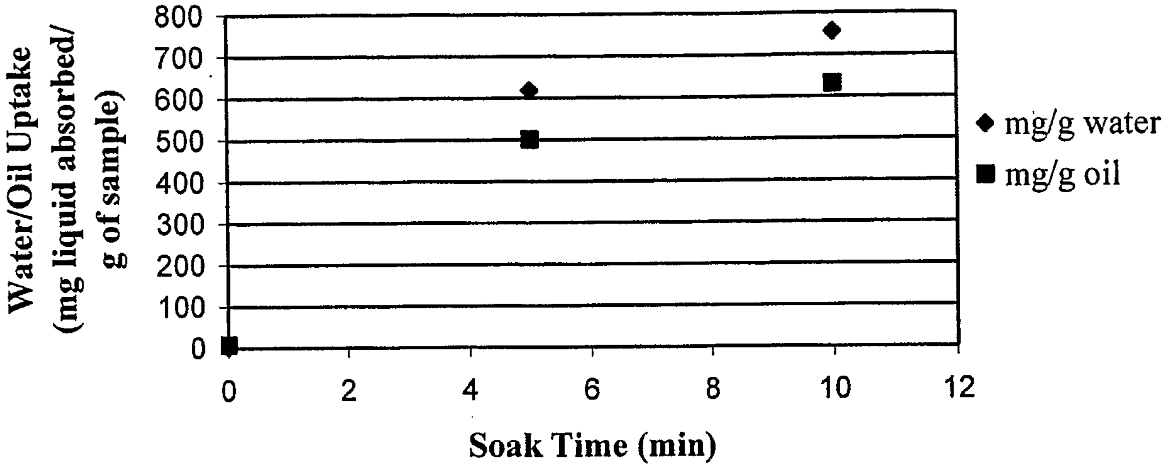

FIGURE 1

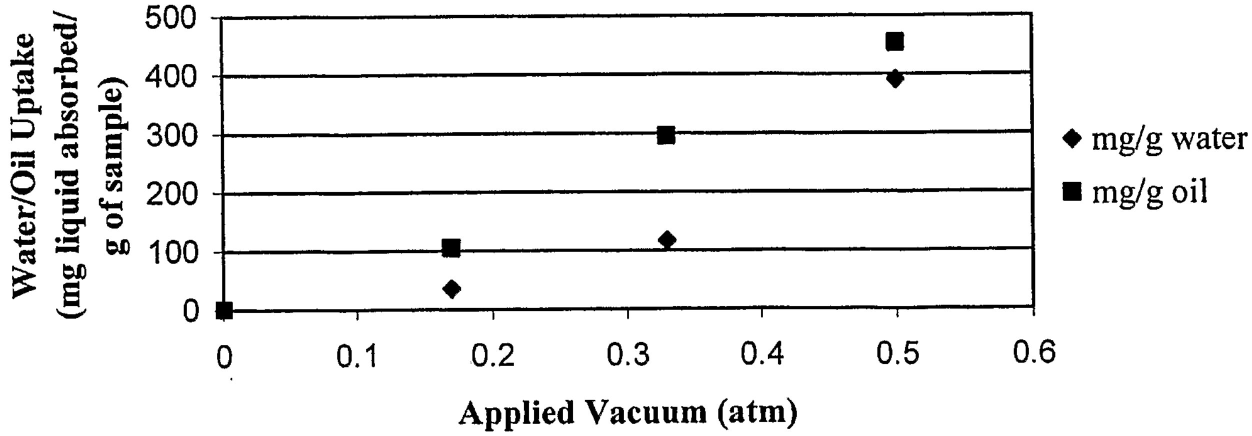

FIGURE 2

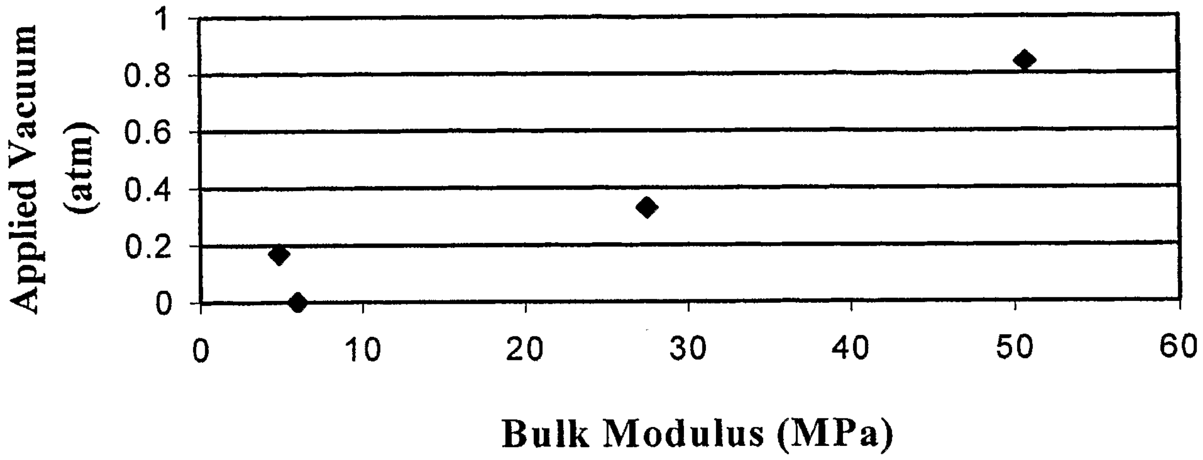
Applied Vacuum (atm)
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
Bulk Modulus (MPa)

FIGURE 3

# INTERNATIONAL SEARCH REPORT

Inter[illegible]nal Application No
PCT/US2005/008527

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC 7 C09G1/02 B24B37/04 H01L21/321

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 C09G B24B H01L B24D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

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☒ Further documents are listed in the continuation of box C.

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° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

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|---|---|
| Date of the actual completion of the international search<br>23 June 2005 | Date of mailing of the international search report<br>05/07/2005 |
| Name and mailing address of the ISA<br>European Patent Office, P.B. 5818 Patentlaan 2<br>NL – 2280 HV Rijswijk<br>Tel. (+31–70) 340–2040, Tx. 31 651 epo nl,<br>Fax: (+31–70) 340–3016 | Authorized officer<br>olde Scheper, B |

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Interr[illegible]nal Application No
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