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(54) SINTERED POLISHING PAD WITH REGIONS OF CONTRASTING DENSITY

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(57) **ABSTRACT**

The invention provides a polishing pad comprising sintered particles of a thermoplastic resin, wherein a surface of the polishing pad intended to contact a substrate to be polished comprises (a) a non-patterned portion with a substantially uniform density and (b) a patterned portion with one or more densities that differ from the density of the non-patterned portion. The invention also provides a method for producing the polishing pad, a chemical-mechanical polishing apparatus comprising the polishing pad, and a method of polishing comprising contacting a substrate with the polishing pad.

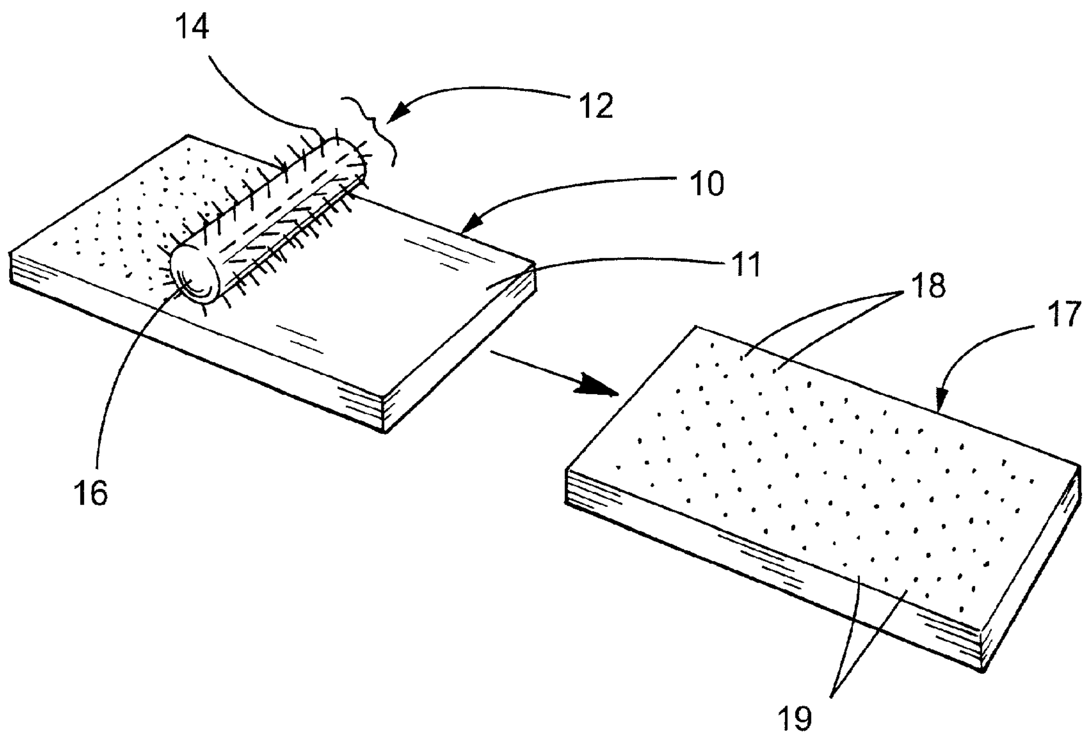


FIG. 1

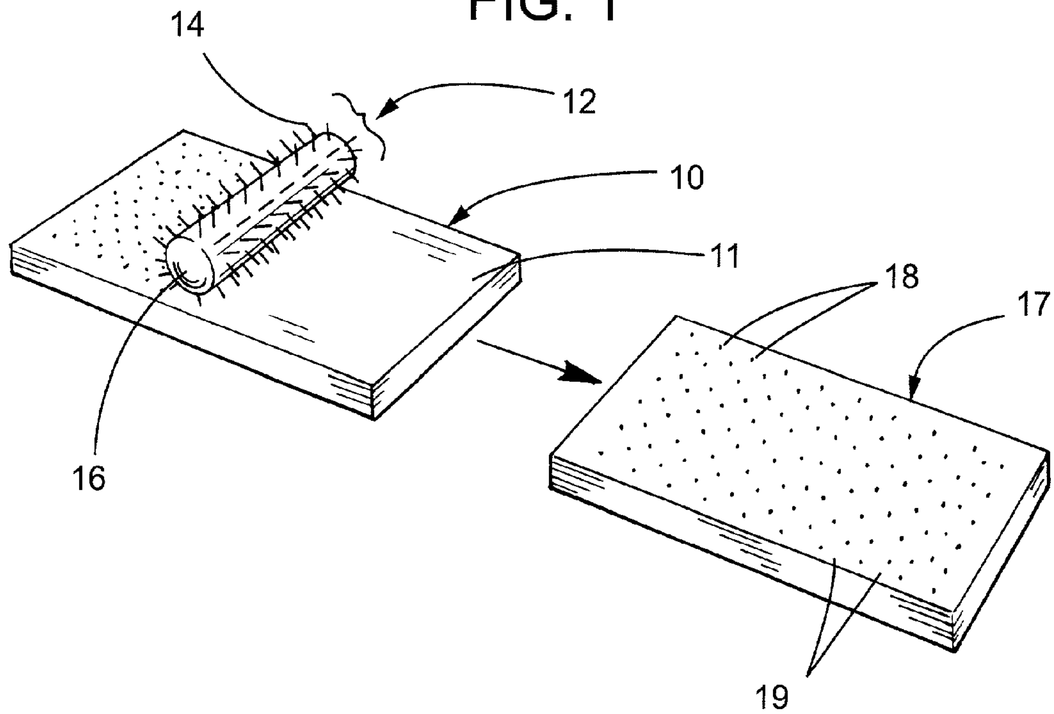


FIG. 2

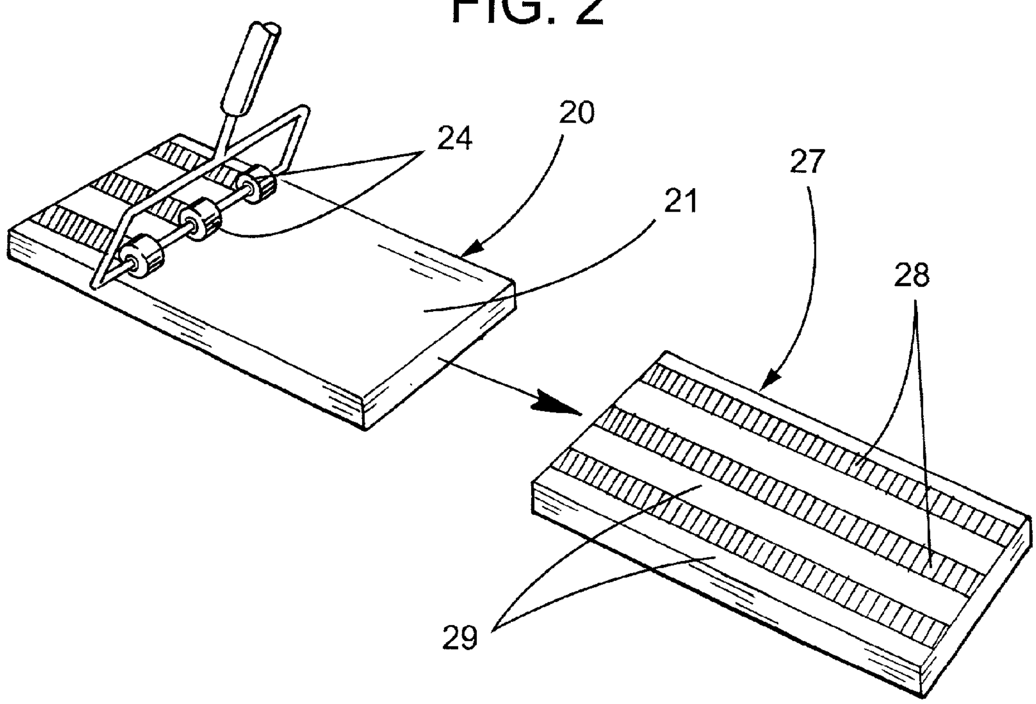


FIG. 3

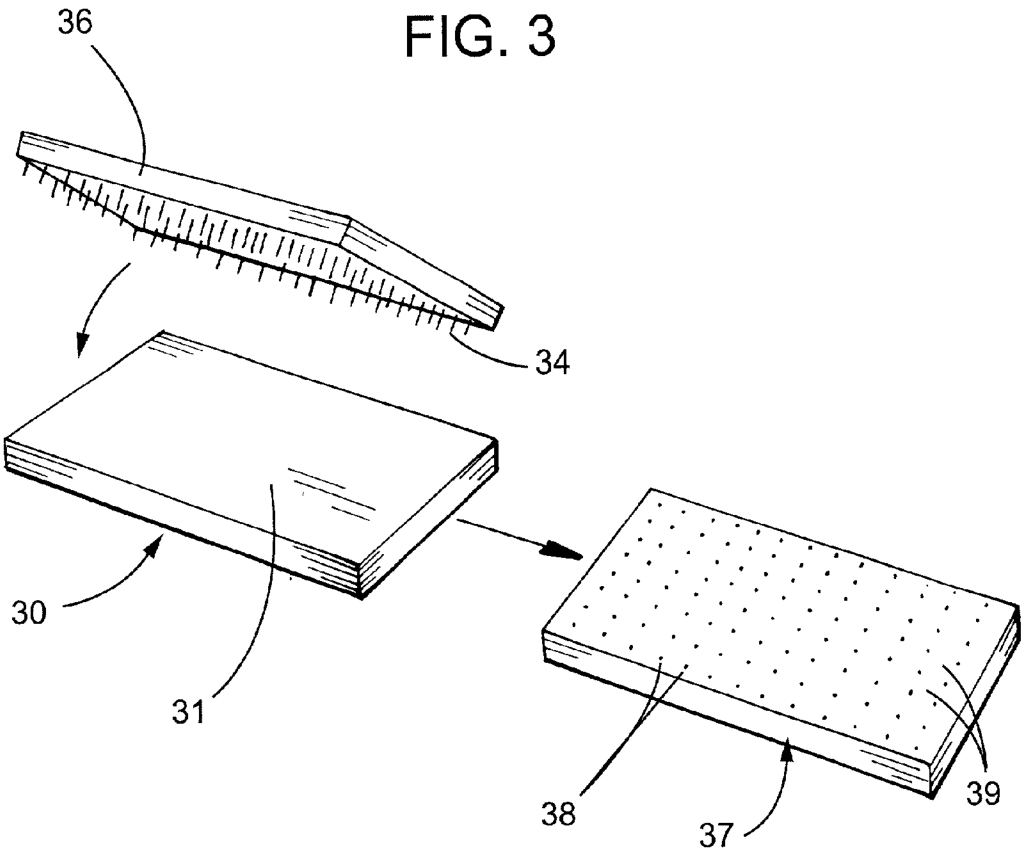
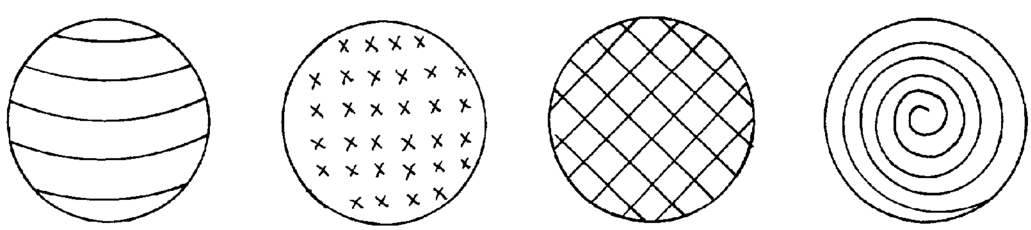


FIG. 4A FIG. 4B FIG. 4C FIG. 4D



SINTERED POLISHING PAD WITH REGIONS OF CONTRASTING DENSITY

FIELD OF THE INVENTION

[0001] This invention pertains to a polishing pad having regions of contrasting density.

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 substrates. 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 substrate 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 optionally 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. Pat. No. 5,489,233). These solid polishing pads are externally modified with large and small grooves that are cut into the surface of the pad purportedly to provide channels for the passage of slurry during chemical-mechanical polishing. A similar non-porous polymer sheet polishing pad is disclosed in U.S. Pat. No. 6,203,407, wherein the polishing surface of the polishing pad comprises grooves that are oriented in such a way that purportedly improves selectivity in the chemical-mechanical polishing. Also in a similar fashion, U.S. Pat. Nos. 6,022,268, 6,217,434, and 6,287,185 disclose hydrophilic polishing pads with no intrinsic ability to absorb or transport slurry particles. The polishing surface purportedly has a random surface topography including microaspersities that are 10 μm or less and formed by solidifying the polishing surface and macro defects (or macrotexture) that are 25 μm or greater and formed by cutting. Sintered polishing pads comprising a porous open-celled structure can be prepared from thermoplastic polymer resins. For example, U.S. Pat. Nos. 6,062,968 and 6,126,532 disclose polishing pads with open-celled, microporous substrates, produced by sintering thermoplastic resins with a pellet size of about 50 to about 200 mesh. The resulting polishing pads preferably have a void volume between 25 and 50% and a density of 0.7 to 0.9 g/cm^3. Similarly, U.S. Pat. Nos. 6,017,265, 6,106,754, and 6,231,434 disclose polishing pads with uniform, continuously interconnected pore structures, produced by sintering thermoplastic polymers at high pressures in excess of 689.5 kPa (100 psi) in a mold having the desired final pad dimensions.

[0005] In addition to groove patterns, polishing pads can have other surface features to provide texture to the surface of the polishing pad. For example, U.S. Pat. No. 5,609,517 discloses a composite polishing pad comprising a support layer, nodes, and an upper layer, all with different hardnesses. U.S. Pat. No. 5,944,583 discloses a composite polishing pad having circumferential rings of alternating compressibility. U.S. Pat. No. 6,168,508 discloses a polishing pad having a first polishing area with a first value of a physical property (e.g., hardness, specific gravity, compressibility, abrasiveness, height, etc.) and a second polishing area with a second value of the physical property. U.S. Pat. No. 6,287,185 discloses a polishing pad having a surface topography produced by a thermoforming process. The surface of the polishing pad is heated under pressure or stress resulting in the formation of surface features.

[0006] Although several of the above-described polishing pads are suitable for their intended purpose, a need remains for an improved polishing pad that provides effective planarization, particularly in substrate polishing by chemical-mechanical polishing. In addition, there is a need for polishing pads having improved polishing efficiency, improved slurry flow across and within the polishing pad, improved resistance to corrosive etchants, and/or improved polishing uniformity. Finally, there is a need for polishing pads that can be produced using relatively low cost methods and which require little or no conditioning prior to use.

[0007] 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

[0008] The invention provides a polishing pad comprising sintered particles of a thermoplastic resin, wherein a surface of the polishing pad intended to contact a substrate to be polished comprises (a) a non-patterned portion with a substantially uniform density and (b) a patterned portion with one or more densities that differ from the density of the non-patterned portion. The invention also provides a method for producing the polishing pad comprising (i) providing a polishing pad with a first density comprising particles of a thermoplastic resin, (ii) heating a portion of the polishing pad to cause the thermoplastic resin particles to flow, and (iii) cooling the polishing pad, thereby causing the flowed thermoplastic resin particles to solidify with a second density that is higher than the first density and forming a polishing pad having a non-patterned portion with the first density and a patterned portion with one or more densities that differ from the density of the non-patterned portion. The invention further provides a chemical-mechanical polishing apparatus comprising the polishing pad, a platen in contact with the polishing pad, and a carrier that holds a substrate to be polished. The invention further provides a method of polishing comprising (i) contacting a substrate with the polishing pad and a polishing composition and (ii) moving the substrate relative to the polishing pad to abrade at least a portion of the substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] **FIG. 1** is an illustration of a polishing pad contacting a heated pattered roller having a plurality of raised pins mounted onto the cylinder of the roller.

[0010] **FIG. 2** is an illustration of a polishing pad contacting a series of small heated rollers that are spaced across the surface of the polishing pad.

[0011] **FIG. 3** is an illustration of a polishing pad contacting a heated pin board having a plurality of raised pins mounted onto the board.

[0012] **FIGS. 4A, 4B**, 4C, and 4D are top views of patterns of a thermal mask to be placed in contact with the surface of a polishing pad to form a patterned portion: semi-circular lines (**FIG. 4A**), isolated regions (**FIG. 4B**), XY crosshatch (**FIG. 4C**), and spiral (**FIG. 4D**).

DETAILED DESCRIPTION OF THE INVENTION

[0013] The invention is directed to a polishing pad comprising sintered particles of a thermoplastic resin. A surface of the polishing pad is intended to contact a substrate to be polished (i.e., the polishing surface) and comprises a non-patterned portion with a substantially uniform density and a patterned portion with one or more densities that differ from the density of the non-patterned portion.

[0014] The polishing surface of the polishing pad comprises patterned features, which make up the patterned portion of the polishing surface. The features can be, for example, XY crosshatch, spirals, concentric rings, a plurality of isolated regions (e.g., dots or polyhedrons), semi-circular lines, or straight lines. The patterned portion of the polishing surface typically comprises one or more of the features. The patterned features, and thus the patterned portion of the polishing surface, can be uniformly distributed (e.g., symmetrically or systematically distributed) over the polishing surface of the polishing pad or can be randomly distributed (e.g., asymmetrically or non-systematically distributed) over the polishing surface of the polishing pad. For example, the patterned feature may be a randomly distributed pattern that is substantially repeated spatially from pad to pad. The location of the patterned portion with respect to the center of the polishing surface of the polishing pad is flexible. The patterned portion may be localized over the center of the polishing surface or may be localized over the periphery of the polishing surface. Typically, the patterned portion of the polishing pad comprises, consists essentially of, or consists of a pattern feature having a minimum dimension (e.g., pattern width) of about 1 mm or more. Preferably, the patterned feature has a minimum dimension of about 2 mm or more (e.g., about 3 mm or more).

[0015] The surface of the polishing pad that is not included in the patterned portion described above is referred to as the non-patterned portion. The non-patterned portion and patterned portion of the polishing pad each have a surface area on the polishing surface. The ratio of the surface area for the non-patterned portion to the surface area of the patterned portion typically is about 95:5 to about 5:95. Preferably, the ratio is about 95:5 to about 50:50. More preferably, the ratio is about 90:10 to about 70:30.

[0016] The non-patterned portion of the polishing pad has a different density than the patterned portion of the polishing pad. The density of the non-patterned and patterned portions of the polishing pad is measured over a polishing pad volume defined in the x and y directions by the patterned or the non-patterned portion of the polishing surface, and in the z direction by the thickness of the polishing pad (i.e., the dimension which connects the polishing surface of the polishing pad and the bottom surface of the polishing pad), particularly the thickness of the patterned features of the polishing pad that becomes exposed or is worn away during the lifetime of the polishing pad. The lifetime of the polishing pad may be indicated by a decrease in polishing performance characteristics, e.g., by a degradation in polishing uniformity, or by reaching the end of the groove depth (if grooved features are formed on the surface of the polishing pad). Typically the amount of the polishing pad exposed during the polishing pad lifetime is about 10% or more (e.g., about 20% or more) of the total polishing pad thickness. More typically, the amount of the polishing pad exposed during the lifetime of the polishing pad is about 30% or more (e.g., about 40% or more) of the total polishing pad thickness. The amount of the polishing pad exposed during the polishing pad lifetime generally is about 90% or less (e.g., about 60% or less).

[0017] Typically, the non-patterned portion of the polishing pad has a substantially uniform density throughout. The patterned portion of the polishing pad typically has one density or more than one density (i.e., multiple different densities) throughout the portion, with at least one such density, and optimally all such densities, differing from the density of the non-patterned portion. Typically, the density of the non-patterned portion is about 0.1 g/cm^3 or higher (e.g., about 0.2 $\mu g/cm^3$ to about 1.1 g/cm^3). Preferably, the non-patterned portion has a density of about 0.5 g/cm^3 to about 0.95 g/cm^3. The patterned portion preferably has a higher density than the non-patterned portion of the polishing pad. For example, the patterned portion typically has a density of about 0.5 g/cm^3 or higher, preferably about 0.7 g/cm^3 or higher, and more preferably about 0.9 g/cm^3 or higher. Preferably, the patterned portion has a density that is about 0.08 g/cm^3 to about 0.5 g/cm^3 higher (e.g., about 0.1 g/cm^3 to about 0.2 g/cm^3 higher) than the density of the non-patterned portion.

[**0018**] The polishing pad typically has a void volume (e.g., porosity) and is therefore not a solid polishing pad. The patterned portion of the polishing pad preferably has a different void volume than the non-patterned portion of the polishing pad. The void volume of the patterned and non-patterned portions is measured using the same total polishing pad volume described above with respect to the density of the patterned and non-patterned portions. The non-patterned portion typically has a higher void volume than the patterned portion of the polishing pad. Preferably, the non-patterned portion of the polishing pad has a void volume of about 10% or more (e.g., about 20% or more or about 30% or more). More preferably, the patterned portion of the polishing pad has a void volume of about 5% to about 30%.

[**0019**] The polishing pad comprises particles of thermoplastic resin. The thermoplastic resin typically is selected from the group consisting of polyvinylchloride, polyvinylfluoride, nylon, fluorocarbon, polycarbonate, polyester, polyacrylate, polymethacrylate, polyether, polyethylene, polyamide, polyurethane, polypropylene, and copolymers and mixtures thereof. Preferably, the thermoplastic resin is a urethane resin.

[**0020**] The non-patterned portion and/or the patterned portion of the polishing pad optionally further comprise grooves on the polishing surface. Such grooves 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. Preferably, the polishing pad at least comprises small grooves produced by standard pad conditioning methods. In one embodiment, for a polishing pad having a patterned portion comprising lines of density, the grooves are oriented perpendicular to the lines of density.

[**0021**] The non-patterned portion and/or the patterned portion of the polishing pad optionally further comprise one or more apertures or translucent regions (e.g., windows). The inclusion of such apertures or translucent regions is desirable when the polishing pad 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 eliminating excess polishing composition on the polishing surface. The translucent region or window can be any suitable window, many of which are known in the art. For example, the translucent 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.

[**0022**] The polishing pad of the invention desirably is produced by (i) providing a polishing pad with a first density comprising particles of a thermoplastic resin, (ii) heating a portion of the polishing pad to cause the thermoplastic resin particles to flow, and (iii) cooling the polishing pad, thereby causing the flowed thermoplastic resin particles to solidify with a second density that is higher than the first density and forming a polishing pad having a non-patterned portion with the first density and a patterned portion with one or more densities that differ form the density of the non-patterned portion.

[**0023**] The polishing pad, prior to the heating step, has a first density corresponding to the density of the polishing pad obtained after sintering particles of the thermoplastic resin. The thermoplastic resin particles can be any of the thermoplastic resin particles described above. The polishing pad, prior to the heating step, has a substantially uniform density throughout the polishing pad. The first density corresponds to the density of the non-patterned portion described above.

[**0024**] One or more portions of the polishing pad having the first density are then heated such that the thermoplastic resin particles begin to flow. In the portions of the polishing pad where the thermoplastic resin particles flow, the density will change such that those portions have a second density that is higher than the first density of the polishing pad.

[**0025**] One or more portions of the polishing pad can be heated by a variety of techniques so as to produce a patterned polishing pad with portions of different density. Preferably, the method of heating does not involve the use of high pressure or stress, which can damage the polishing pad. For example, a portion of the polishing pad can be heated by contacting the polishing pad with one or more patterned rollers as depicted in **FIG. 1** and **FIG. 2**. In **FIG. 1, a** polishing pad (**10**) of a first density has a polishing surface (**11**) that is contacted with a patterned roller (**12**), which consists of heated pins (**14**), or other raised, shaped features, mounted onto a cylinder (**16**). The resulting polishing pad (**17**) has a patterned portion consisting of spaced regions (**18**) that are areas of a second, higher density, and a non-patterned portion (**19**) that retains the first density. In **FIG. 2, a** polishing pad (**20**) has a polishing surface (**21**) that is contacted with multiple rollers (**24**) that are spaced apart relative to the surface of the polishing pad. The resulting polishing pad (**27**) has a patterned portion (**28**) consisting of separated lines of the second, higher density, and a non-patterned portion (**29**) that retains the first density. Alternatively, a portion of the polishing pad can be heated by contacting a polishing pad with a heated pin board as depicted in **FIG. 3**. In **FIG. 3, a** polishing pad (**30**) has a polishing surface (**31**) that is contacted with a pin board (**32**), which consists of heated pins (**34**), or other raised, shaped features, mounted onto a board (**36**). The resulting polishing pad (**37**) has a patterned portion consisting of spaced regions (**38**) that are areas of a second, higher density, and a non-patterned portion (**39**) that retains the first density. A portion of the polishing pad also can be heated by contacting the polishing pad with a patterned mask in the presence of an external heat or radiation source. Examples of suitable external heat or radiation sources include jets of hot air, lasers, microwave radiation, or ultraviolet radiation. The patterned mask can have one or more of the pattern designs described above including semi-circular lines, a plurality of isolated regions, XY crosshatch, spirals, as depicted in FIGS. **4A-4D**, respectively, or other patterns such as concentric rings and straight lines.

[**0026**] After heating one or more portions of the polishing pad, the polishing pad is cooled such that the heated portions of the polishing pad solidify to the second density. The resulting polishing pad has a non-patterned portion, which retains the first density and a patterned portion, which has a second density. The second density will be different from and higher than the first density. The patterned portion of the polishing pad can have two or more second densities that are different from the first density. Typically, the two or more second densities will be part of a continuum of increasing density.

[0027] 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 platen that rotates, a polishing pad of the invention in contact with the platen and rotating with the platen, and a carrier that holds a substrate to be polished by contacting the surface of the polishing pad intended to contact a substrate to be polished. The polishing of the substrate takes place by the substrate being placed in contact with the polishing pad and then the polishing pad moving relative to the substrate, typically with a polishing composition therebetween, so as to abrade at least a portion of the substrate to polish the substrate. 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.

[0028] The polishing pad described herein is suitable for use in polishing many types of substrates and substrate materials. For example, the polishing pad can be used to polish a variety of substrates including memory disks, semiconductor wafers, field emission displays, and other microelectronic substrates, especially substrates comprising insulating layers (e.g., oxide, nitride, or low dielectric materials), and/or metal-containing layers (e.g., copper, tantalum, tungsten, aluminum, nickel, titanium, platinum, ruthenium, rhodium, iridium or other noble metals).

[0029] All references, including publications, patent applications, and patents, cited herein are hereby incorporated by reference to the same extent as if each reference were individually and specifically indicated to be incorporated by reference and were set forth in its entirety herein.

[0030] The use of the terms "a" and "an" and "the" and similar referents in the context of describing the invention (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. The terms "comprising,""having,""including," and "containing" are to be construed as open-ended terms (i.e., meaning "including, but not limited to,") unless otherwise noted. Recitation of ranges of values herein are merely intended to serve as a shorthand method of referring individually to each separate value falling within the range, unless otherwise indicated herein, and each separate value is incorporated into the specification as if it were individually recited herein. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use of any and all examples, or exemplary language (e.g., "such as") provided herein, is intended merely to better illuminate the invention and does not pose a limitation on the scope of the invention unless otherwise claimed. No language in the specification should be construed as indicating any non-claimed element as essential to the practice of the invention.

[0031] Preferred embodiments of this invention are described herein, including the best mode known to the inventors for carrying out the invention. Variations of those preferred embodiments may become apparent to those of ordinary skill in the art upon reading the foregoing description. The inventors expect skilled artisans to employ such variations as appropriate, and the inventors intend for the invention to be practiced otherwise than as specifically described herein. Accordingly, this invention includes all modifications and equivalents of the subject matter recited in the claims appended hereto as permitted by applicable law. Moreover, any combination of the above-described elements in all possible variations thereof is encompassed by the invention unless otherwise indicated herein or otherwise clearly contradicted by context.

What is claimed is:

1. A polishing pad comprising sintered particles of a thermoplastic resin, wherein a surface of the polishing pad intended to contact a substrate to be polished comprises a non-patterned portion with a substantially uniform density and a patterned portion with one or more densities that differ from the density of the non-patterned portion.

2. The polishing pad of claim 1, wherein the patterned portion is uniformly distributed on the surface of the polishing pad.

3. The polishing pad of claim 1, wherein the patterned portion is randomly distributed on the surface of the polishing pad.

4. The polishing pad of claim 1, wherein the patterned portion comprises one or more features selected from the group consisting of XY crosshatch, spirals, concentric rings, a plurality of isolated regions, semi-circular lines, and straight lines.

5. The polishing pad of claim 1, wherein the non-patterned portion has a density of about 0.2 g/cm^3 to about 1.1 g/cm^3.

6. The polishing pad of claim 1, wherein the patterned portion has at least one density of about 0.5 g/cm^3 or higher.

7. The polishing pad of claim 5, wherein the patterned portion has a density that is about 0.1 to about 0.2 g/cm^3 higher than the density of the non-patterned portion.

8. The polishing pad of claim 1, wherein the ratio of surface area of the patterned portion to non-patterned portion is about 95:5 to about 50:50.

9. The polishing pad of claim 1, wherein the patterned portion comprises patterned features having a minimum dimension of about 2 mm or more.

10. The polishing pad of claim 1, wherein the thermoplastic resin is selected from the group consisting of polyvinylchloride, polyvinylfluoride, nylon, fluorocarbon, polycarbonate, polyester, polyacrylate, polymethacrylate, polyether, polyethylene, polyamide, polyurethane, polypropylene, and copolymers and mixtures thereof.

11. The polishing pad of claim 9, wherein the thermoplastic resin is a urethane resin.

12. The polishing pad of claim 1, wherein the patterned portion has at least one density that is higher than the non-patterned portion of the polishing pad.

13. The polishing pad of claim 1, wherein the patterned portion has a lower void volume than the non-patterned portion of the polishing pad.

14. The polishing pad of claim 1, the patterned portion further comprises one or more features selected from the group consisting of grooves and translucent window regions.

15. A method for producing a polishing pad comprising:

(a) providing a polishing pad with a first density comprising particles of a thermoplastic resin,

(b) heating a portion of the polishing pad to cause the thermoplastic resin particles to flow, and

(c) cooling the polishing pad, thereby causing the flowed thermoplastic resin particles to solidify with a second density that is higher than the first density and forming a polishing pad having a non-patterned portion with the first density and a patterned portion with one or more densities that differ from the density of the non-patterned portion.

16. The method of claim 15, wherein the thermoplastic resin is selected from the group consisting of polyvinylchloride, polyvinylfluoride, nylon, fluorocarbon, polycarbonate, polyester, polyacrylate, polymethacrylate, polyether, polyethylene, polyamide, polyurethane, polypropylene, and copolymers and mixtures thereof.

17. The method of claim 15, wherein the thermoplastic resin is a urethane resin.

18. The method of claim 15, wherein a portion of the polishing pad is heated by contacting the polishing pad with one or more patterned rollers.

19. The method of claim 18, wherein the patterned rollers comprise raised features mounted onto a cylinder.

20. The method of claim 15, wherein a portion of the polishing pad is heated by contacting the polishing pad with a pin board.

21. The method of claim 15, wherein a portion of the polishing pad is heated by contacting the polishing pad with a patterned mask in the presence of an external heat or radiation source.

22. The method of claim 15, wherein a portion of the polishing pad is heated by contacting the polishing pad with jets of hot air.

23. A chemical-mechanical polishing apparatus comprising:

(a) a platen that rotates,

(b) a polishing pad of claim 1, wherein the polishing pad is in contact with the platen and rotates with the platen, and

(c) a carrier that holds a substrate to be polished by contacting the surface of the polishing pad intended to contact a substrate to be polished.

24. A method of polishing comprising:

(a) contacting a substrate with the polishing pad of claim 1 and a polishing composition,

(b) moving the substrate relative to the polishing pad to abrade at least a portion of the substrate to polish the substrate.

25. The method of claim 24, wherein the substrate comprises an insulating layer selected from silicon dioxide, silicon nitride, and a dielectric material having a dielectric constant of about 3.5 or lower.

26. The method of claim 24, wherein the substrate comprises a metal-containing layer comprising copper, tantalum, tungsten, aluminum, nickel, titanium, platinum, ruthenium, rhodium, or iridium.

27. The method of claim 24, wherein the polishing composition comprises an abrasive, a liquid carrier, and optionally an oxidizer or complexing agent.

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