



(19) **United States**

(12) **Patent Application Publication**

Ramana et al.

(10) **Pub. No.: US 2001/0046834 A1**

(43) **Pub. Date: Nov. 29, 2001**

(54) **PAD SURFACE TEXTURE FORMED BY SOLID PHASE DROPLETS**

(76) Inventors: **Anuradha Ramana**, Newark, DE (US);
Elmer W. Jensen JR., Chadds Ford, PA (US)

Correspondence Address:
Rodel Holdings, Inc.
Suite 1300
1105 North Market Street
Wilmington, DE 19899 (US)

(21) Appl. No.: **09/795,242**
(22) Filed: **Feb. 28, 2001**

Related U.S. Application Data

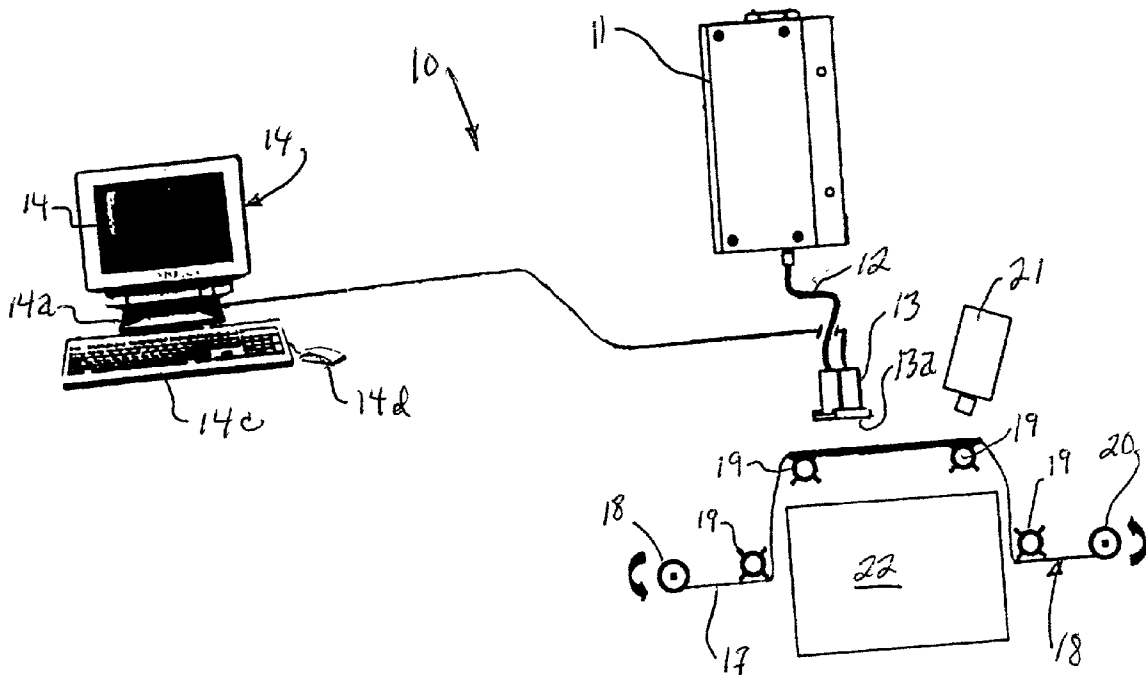
(63) Non-provisional of provisional application No. 60/185,483, filed on Feb. 28, 2000.

Publication Classification

(51) **Int. Cl.⁷** **B24D 11/00**
(52) **U.S. Cl.** **451/526**

(57) **ABSTRACT**

A polishing pad is made by a piezoelectric delivery system, and a method of making the pad includes, building successive layers of droplets of material one layer on another layer by dispensing the material in fluid phase as droplets arranged in a droplet pattern, and solidifying the droplets in the droplet pattern to provide the polishing surface with a surface texture having recesses bounded by the droplets in the droplet pattern.



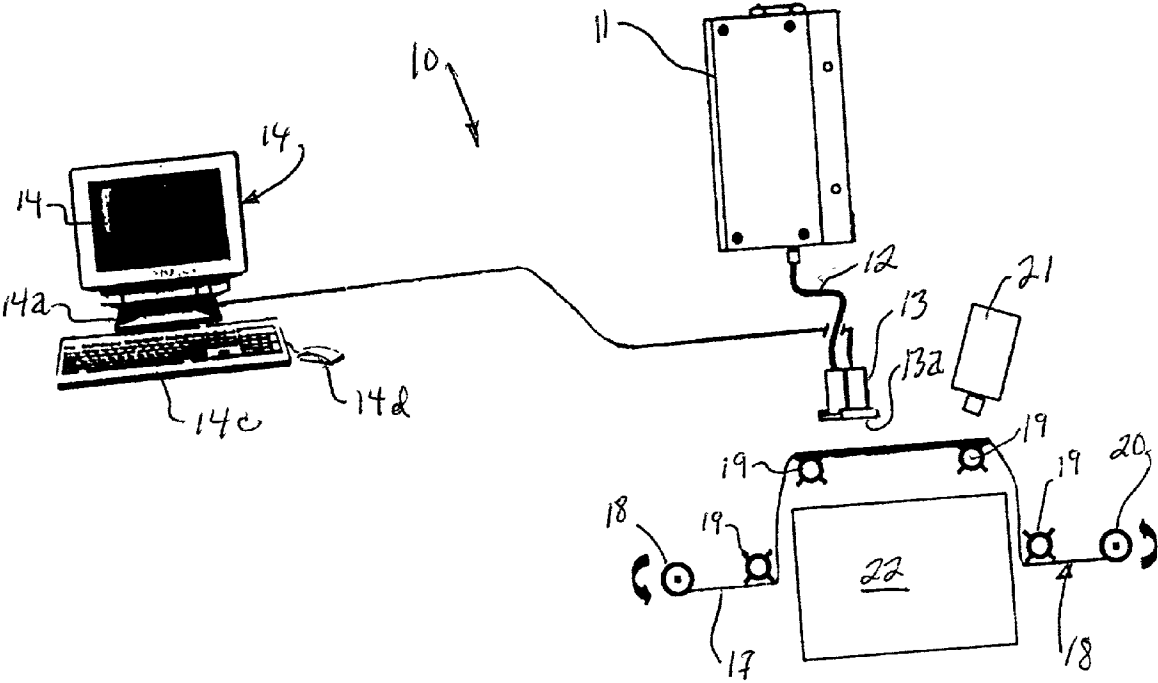


Fig. 1

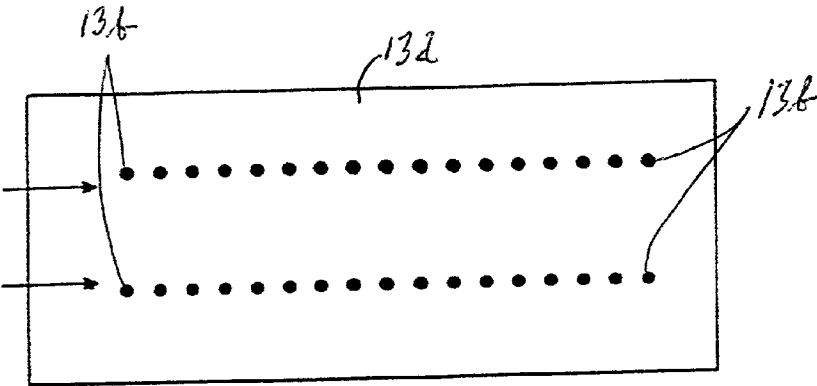
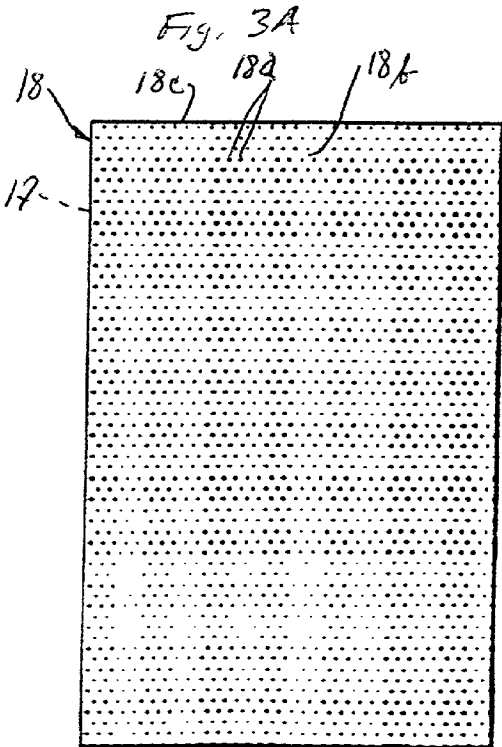
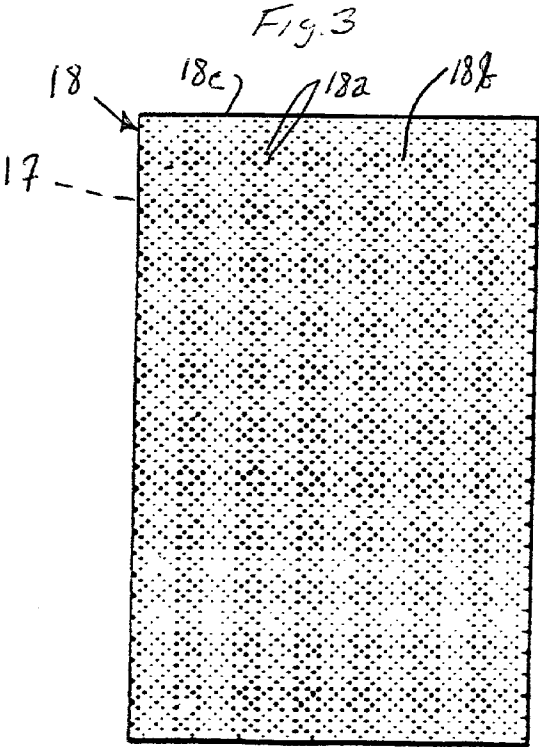


Fig. 2



PAD SURFACE TEXTURE FORMED BY SOLID PHASE DROPLETS

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of provisional application Ser. No. 60/185,483 filed Feb. 28, 2000.

BACKGROUND OF THE INVENTION

[0002] 1. Field Of The Invention

[0003] The present invention relates to a polishing pad and a process for making a polishing surface on a polishing pad that polishes articles, such as, semiconductors, integrated circuits, and glass substrates.

[0004] 2. Discussion Of Related Art

[0005] A polishing process is performed by rubbing a moving polishing pad against a surface of an article being polished, while a fluid polishing composition is applied at an interface of the polishing pad and the article being polished. Polishing removes material from the article at a controlled rate, and produces a smooth, planar polished surface on the article. The polishing composition includes an aqueous solution of chemical constituents that react selectively with the material of the article to enhance its removal by polishing. Further the polishing composition can include a liquid suspension of particulates of polishing abrasives for abrading the article. Further the polishing composition can include a liquid suspension of particulates of substances that chemically bond to selected material on the article being polished to inhibit polishing and removal of the selected material. The pads themselves can include particulates of abrasives or can be free of particulates of abrasives.

[0006] U.S. Pat. 5,489,233 discloses known polishing pads having polishing surfaces on which surface texture is provided to transport polishing composition across the polishing surfaces, and provide active polishing activity of the pads. The surface texture is identified as either macrotexture or microtexture. Macrotexture is texture in the form of recesses with dimensions of depths and spacings apart that are clearly visible to the unaided eye. Microtexture is texture in the form of recesses of smaller dimensions than those of macrotexture. The surface texture, including macrotexture and microtexture, of known polishing pads is provided by mechanical production and/or by the material structure of the polishing pads.

[0007] Known polishing pads are fabricated of materials in bulk that are bulk processed, for example, by combining particulates and fluid phase materials with fibrous materials, and by agglomerating, depositing, molding, casting or sintering nonfibrous materials. Further, bulk processing is performed by a series of batch processes that result in batch to batch variation among the pads. Such pads are intended to have the same surface texture. However the surface textures vary, which produce different polishing performances that are difficult to predict. What is desired is a manufacturing process that produces a desired surface texture on a polishing surface, with minimized variation of the surface texture among multiple pads intended to have the same surface texture. Further, what is desired is a surface texture on a polishing surface of a polishing pad, which surface texture has recesses of controlled dimensions and controlled spac-

ings apart to minimize variations among multiple pads intended to have the same surface texture.

SUMMARY OF THE INVENTION

[0008] The invention advantageously provides a polishing surface on a polishing pad and a surface texture. The invention is directed to polishing surface on a polishing pad, wherein the polishing surface is constructed of successive layers of solidified droplets of material, the droplets are arranged in a pattern of droplets in each of the layers, and a surface texture of the polishing surface is provided by recesses bounded by the droplets in the pattern of droplets.

[0009] Further, the invention is directed to a process for making a polishing surface on a polishing pad by; building successive layers of droplets of material one layer on another layer by dispensing the material in fluid phase as droplets arranged in a droplet pattern, and solidifying the droplets in the droplet pattern to provide the polishing surface with a surface texture having recesses bounded by the droplets in the droplet pattern.

[0010] An embodiment of the invention will now be described by way of example, with reference to the accompanying drawings, according to which:

DESCRIPTION OF THE DRAWINGS

[0011] FIG. 1 is a schematic view of apparatus including a piezoelectric delivery system for making a polishing surface on a polishing pad.

[0012] FIG. 2 is bottom view disclosing multiple nozzles of a piezoelectric printer head for producing droplets of material in liquid phase that are solidified to provide a surface texture that has recesses of controlled dimensions and controlled spacings apart to minimize variations among multiple pads intended to have the same surface texture.

[0013] FIG. 3 is a magnified top view of part of a polishing surface having a surface texture with recesses bounded by solidified droplets of material arranged in a first pattern of droplets.

[0014] FIG. 3A is a magnified top view of part of another polishing surface having a surface texture with recesses bounded by solidified droplets of material arranged in a second pattern of droplets.

DETAILED DESCRIPTION

[0015] FIG. 1 discloses a piezoelectric delivery system 10 for dispensing material of liquid phase as droplets. Such material is solidifiable subsequent to being dispensed. The delivery system 10 includes an apparatus having a reservoir 11 connected by a flexible conduit 12 to a computer controlled, piezoelectric printer 13 that is controlled by a conventional computer 14 to which the printer 13 is connected by an electrical communications cable 15. The computer 14 has a central processing unit, CPU, 14a, a video display screen 14b and command input devices 14c, 14d, such as a keyboard and a mouse. The computer 14 is programmed for the computer 14 to actuate the various parts of the delivery system 10 according to a sequence of process steps. The reservoir 11 stores material in liquid phase and supplies such material under pressure along the conduit 12 to the printer 13. Further, the delivery system 10, as dis-

closed by FIG. 1, includes a computer controlled work station 16. A flexible continuous base layer or substrate 17 of a polishing pad 18 is provided as a continuous roll on a supply spool 18, and is driven by a series of rotating drive rollers 19 across the work station 16 and to a take up spool 20. The computer 14 controls the drive rollers 19 to turn and supply the base layer or substrate 17 of the polishing pad 18 under a piezoelectric printer head 13a of the printer 13, while the printer head 13a dispenses the material of fluid phase as droplets 18b, FIGS. 3 and 3A, arranged in a pattern of droplets 18b onto the base layer or substrate 17 that is disclosed in FIGS. 3 and 3A as being under the droplets 18b.

[0016] As disclosed by FIG. 2, the printer head 13a has multiple dispensing nozzles 13b that dispense the material of liquid phase. Each of the nozzles 13b has an opening of sufficient size to pass large molecules of material of liquid phase as droplets 18b. According to a known operation of a piezoelectric printer head 13a, the computer 14 controls the printer 13 to generate a piezoelectric pulse at the printer head 13a, to exert a pulsed increase in pressure on the material of fluid phase, which causes a droplet 18b of the material to dispense from each nozzle 13b. While such droplets 18b are being dispensed from respective nozzles 13b, the computer 14 controls the printer head 13a to traverse back and forth, making a predetermined number of back and forth passes, as determined by the computer 14. Thereby, the printer 13 dispenses droplets 18b in a pattern of droplets 18b, for example, one of the exemplary patterns, as disclosed by FIGS. 3 and 3A. The droplets 18b in each of the patterns are solidified, for example, by drying. By solidifying the droplets 18b in the patterns, a polishing layer 18c is provided on the polishing pad 18, with an exterior surface of the polishing layer 18c providing a polishing surface on the polishing pad 18. Further, the polishing surface is provided with a surface texture having recesses 18a bounded by the droplets 18b in the pattern of droplets 18b. In each of FIGS. 3 and 3A, the recesses 18a are disclosed as dark recesses 18a bounded by the solidified droplets 18b that are disclosed as light areas. Although the dark recesses 18a are disclosed with dotted shapes, they may also include other shapes, such as grooves or channels. Those recesses 18a that are visible to the unaided eye provide the polishing surface with macrotexture. Those recesses 18a of smaller dimensions than those that are visible to the unaided eye provide the polishing surface with microtexture. According to the invention, a process of printing provides, either macrotexture or microtexture, or both macrotexture and microtexture. Such a process is repeatable by the computer controlled, piezoelectric delivery system 10, to minimize variation of surface texture among multiple pads 18 made by such a delivery system 10. Additionally, the piezoelectric delivery system 10 eliminates a need for production of the surface texture by mechanical production on a prior manufactured polishing surface.

[0017] With reference to FIG. 1, after droplets 18b are dispensed on the substrate 17, they are solidified by air drying, or are cured by an energy providing, curing apparatus, such as, a gun 21 or a conventional oven 22. The gun 21 is either a heat gun providing radiant heat or a UV (ultraviolet light) gun or a laser gun (D). The computer 14 controls the gun 21 to provide either a continuous curing cycle or an intermittent curing cycle, as needed to solidify the droplets 18b for permanent location within a desired

pattern of droplets 18b. Alternatively, the droplets 18b are cured by the heat of a conventional oven 22.

[0018] According to an embodiment, the material of liquid phase includes, an hydrophilic polymer mixture of the polymer or precursor thereto and a solvent of the polymer. According to another embodiment, the material of liquid phase further includes a liquid suspension of submicron size particulates of abrasives.

[0019] According to a further embodiment, the material of liquid phase includes, polymer/solvent mixtures, low molecular weight liquid polymers or oligomers on appropriate substrates resulting in films or coatings with unique surface properties (adhesion, wettability, electrical conductivity and the like).

[0020] According to an embodiment, the piezoelectric delivery system 10 makes a pattern of droplets 18b that extends through the thickness of an entire polishing layer 18c on the base layer or substrate 17. The pattern of droplets 18b is retained on the polishing surface of the polishing layer 18c, as the polishing layer 18c wears during use. The polishing layer 18c is built up to a thickness in the range of 0.05 to 0.2 millimeters by a number of repeated passes of the printer head 13a. The desired thickness of the polishing layer 18c determines the number of times the printer head 13a traverses over the substrate 17. Surface texture is obtained by controlling the number and location of nozzles 13b, and by the sizes and locations of the dispensed droplets 18b. A polishing pad 18 made this process can be used for conventional polishing in which the pad 18 is used in combination with a fluid polishing composition, either containing particulates of a polishing abrasive or other material, or that is free of abrasive type of particulates.

[0021] According to an embodiment, the work station 16 includes a cutter/plotter, and is commercially available from Roland Inc. The piezoelectric printer head 13a is supplied by On-Target Technology, Inc. An embodiment of a laser gun 21 is typically an Argon ion laser (intensity of 1 kW per sq.cm.) or Nd: YAG laser with a pulse energy of 250 mJ, pulse duration of 10 ns and a frequency of 10 Hz..

[0022] An embodiment of the substrate 17 can comprise a single layer or multiple layers and can comprise of a combination of layers that are bonded together. The substrate 17 is preferably a flexible web capable of being pulled from a roll or easily wound into a roll. Preferred substrates 17 are plastics, such as engineered plastics, for example a polyamide, polyimide, and/or polyester, particularly "PET" poly(ethylene terephthalate). Woven and non-woven webs of polyamide fibers, polyimide fibers, polyester fibers such as PET also can be used. The substrate 17 has a thickness of about 0.5-1.5 millimeters.

[0023] In another embodiment of this invention, the polishing layer 18c material comprises: rigid domains which resist plastic flow during polishing; and less rigid domains which are less resistant to plastic flow during polishing. The hard domains rigorously engage the article being polished.

[0024] The rigid and non-rigid domain sizes in any dimension (height, width or length) is preferably in the range of 0.05 to 0.1 millimeters. Preferred dual domain materials include polyurethane polymers having a soft segment (which provides the non-rigid phase) and a hard segment (which provides the rigid phase). The domains may be

produced during the forming of the polishing layer by a phase separation, due to incompatibility between the two (hard and soft) polymer segments. Hard and soft domains within the pad material can also be created: by hard and soft segments along a polymer backbone; by crystalline and non-crystalline regions within the pad material; by alloying a hard polymer with a soft polymer; or by combining a polymer with an organic (latex spheres) or abrasives such as ceric oxide, silicon dioxide, zirconium oxide and the like. The preferred technique for generating hard and soft domains in polishing pads generated by the process of this invention is to use a combination of an organic polymer and abrasives described above.

[0025] In another embodiment of this invention, thin polishing layers **18c** in the range of 0.05 to 0.2 millimeters comprise a random surface texture comprising recesses **18a** of varying sizes and dimensions. In another embodiment, the polishing layer **18a** contains about 30 to 75% by weight abrasives in the form of particulates. Other components can include organic fillers (e.g. latex spheres), organic binders (e.g. acrylic polymers), viscosity modifiers (e.g. polyethylene glycol) and organic additives to control the evaporation rate of the material. Abrasives used in the polishing layer are ceric oxide, silicon dioxide, aluminum oxide, zirconium oxide or any mixtures thereof. A combination of these abrasives may also be used to give the polishing layer **18c** appropriate hardness and density.

[0026] To obtain adequate adhesion of a hydrophilic type of polishing layer **18c** to the flexible base substrate **17**, the substrate **17** can be treated. Treatment for this purpose includes UV curing (to promote wettability) or a coating with an adhesion promoter (solvent-based binder). Commercially available substrates **17** can be coated with binders to enhance adhesion of a hydrophilic polishing layer **18c**.

EXAMPLE 1

[0027] A composition was prepared for deposition via a piezoelectric material delivery system **10**. The composition is a mixture of an abrasive (ceric oxide), a solvent and a solvent based acrylic polymer having a T_g (glass transition temperature) of 50-60° C. The composition was charged into the reservoir **11** (**FIG.1**) and deposited via the piezoelectric printer head **13a**. The substrate **17** is a polyethylene terephthalate film precoated with an adhesion promoting material. The droplets **18b** are deposited on the substrate **17**, and are solidified by being thermally cured by a conventional forced air oven **22**.

[0028] It is expected that a variety of different compositions used for forming the polishing layer **18c** of a polishing pad **18** can be deposited via the piezoelectric material delivery system **10** on a variety of substrates **17** and after deposition cured thermally or via a laser gun **21** to form polishing pads **18**. The pattern of the droplets **18b** and the thickness of the polishing layer **18c** can be changed, as controlled by the computer **14**. The resulting polishing pads **18** should be useful for polishing articles, such as, electrical devices, silicon wafers, semiconductor substrates and glass.

[0029] The invention applies to the manufacture of a polishing pad **18** for planarizing a surface of a semiconductor device or a precursor thereto, said pad **18** including, for example, a polishing layer **18c** for planarizing said surface, said layer **18c** having: a hardness of about 40-70 Shore D,

a tensile Modulus of about 150-2,000 Mpa at 40° C, an energy loss factor, KEL, of about 100-1,100 (1/Pa at 40° C), and an elastic storage modulus, E', ratio at 30° C-90° C of about 1-4.6, as described in U.S. Pat. Application Ser. No. 09/608,537 filed Jun. 30, 2000, which claims the benefit of provisional application 60/207,938 filed May 27, 2000, hereby incorporated by reference herein.

[0030] Further, the invention applies to the manufacture of a polishing pad **18** for planarizing a surface of a semiconductor device or precursor thereto, said surface having a **10** micron width metal line, the pad **18** comprising a stiff polishing layer **18c** containing a polymer system which provides sufficient energy dissipation and low elastic recovery to provide less than 500 Angstroms of dishing on the metal line, as described in U.S. Pat. Application Ser. No. 09/608,537 filed Jun. 30, 2000, that claims the benefit of provisional application Ser. No. 60/207,938 filed May 27, 2000, hereby incorporated by reference herein.

[0031] Further, the invention applies to the manufacture of a polishing pad **18** for planarizing a surface of a semiconductor device or a precursor thereto, said pad **18** further including, for example, a polishing layer **18c** for planarizing said surface, said layer **18c** having: a thickness of about 250 to 5,100 micrometers, a hardness of about 40-70 Shore D, a tensile Modulus of about 150-2,000 Mpa at 40° C, an energy loss factor, KEL, of about 100-1,100 (1/Pa at 40° C), and an elastic storage modulus, E', ratio at 30° C and 90° C of about 1-5, wherein said polishing layer **18c** is further defined as having a macro-texture comprising a groove pattern having one or more grooves, said groove pattern having: a groove depth of about 75 to about 2,540 micrometers, a groove width of about 125 to about 1,270 micrometers, and a groove pitch of about 500 to 3,600 micrometers, and said groove pattern being concentric, spiral, cross-hatched, X-Y grid, hexagonal, triangular, fractal or a combination thereof, as described in U.S. Pat. Application Ser. No. 09/631,783 filed Aug. 3, 2000. Further, the invention applies to the manufacture of a polishing pad **18** for planarizing a surface of a semiconductor device or a precursor thereto, said pad **18** including, for example, a polishing layer **18c** for planarizing said surface, said layer **18c** having, an Elastic Storage Modulus, E', ratio at 30° C and 90° C of about 1-3.6, as described in U.S. patent application Ser. No. 09/631,783 filed Aug.3, 2000, that claims the benefit of provisional application Ser. No. 60/207,938 filed May 27, 2000, and that claims the benefit of provisional application Ser. No. 60/222,099 filed Jul. 28, 2000, hereby incorporated by reference herein.

[0032] Further, the invention applies to the manufacture of a hydrolytically stable polishing pad **18** for planarizing a surface of a semiconductor device or a precursor thereto, said pad **18** including, for example, a polishing layer **18c** for planarizing said surface, said layer **18c** having: a thickness of about 250 to 5,100 micrometers, a hardness of about 40-70 Shore D, a tensile Modulus of about 150-2,000 Mpa at 40° C, an energy loss factor, KEL, of about 100-1,100 (1/Pa at 40° C), and an elastic storage modulus, E', ratio at 30° C and 90° C of about 1-5, wherein said polishing layer **18c** is further defined as having a macro-texture comprising a groove pattern having one or more grooves, said groove pattern having: a groove depth of about 75 to about 2,540 micrometers, a groove width of about 125 to about 1,270 micrometers, and a groove pitch of about 500 to 3,600

micrometers and said groove pattern being random, concentric, spiral, cross-hatched, X-Y grid, hexagonal, triangular, fractal or a combination thereof, as described in U.S. patent application Ser. No. 09/665,841 filed Sep. 20, 2000. Further, the invention applies to the manufacture of a polishing pad **18** for planarizing a surface of a semiconductor device or precursor thereto, said surface having a 10 micron width metal line, the pad **18** comprising a stiff polishing layer **18c** containing a polymer system which provides sufficient energy dissipation and low elastic recovery to provide less than 0.5 micrometers of dishing on the metal line, as described in U.S. Patent Application Ser. No. 09/665,841 filed Sep. 20, 2000, hereby incorporated by reference herein.

[0033] Preferred embodiments having been described, other embodiments and modifications of the invention are intended to be covered by the spirit and scope of the appended claims.

What is claimed is:

1. A process for making polishing pads useful in the manufacture of a semiconductor device or a precursor thereto, comprising applying a material comprising a hydrophilic polymer and abrasive to a flexible base substrate using a piezoelectric material delivery system to form a polishing layer on the substrate and curing the deposited polishing layer.

2. The process of claim 1 in which a multiplicity of layers are applied to a desired pattern and thickness to form the polishing layer and the layer is cured thermally or with a laser.

3. The process of claim 2 in which the piezoelectric material delivery system comprises a piezoelectric printer.

4. A method for making a polishing surface on a polishing pad, comprising the steps of: building successive layers of droplets of material one layer on another layer by dispensing the material in fluid phase as droplets arranged in a droplet

pattern, and solidifying the droplets in the droplet pattern to provide the polishing surface with a surface texture having recesses bounded by the droplets in the droplet pattern.

5. The method of claim 4 wherein, the step of building successive layers of material further comprises the step of: dispensing the material in fluid phase as droplets of different sizes.

6. The method of claim 4 wherein, the step of dispensing the material in fluid phase as droplets, further comprises the step of: dispensing the material in fluid phase as droplets of polymeric material in a solvent of the polymeric material.

7. The method of claim 4 wherein, the step of building successive layers of material further comprises the step of, dispensing particulates in suspension with the material in fluid phase; and the step of solidifying the droplets in the droplet pattern further comprises the step of, solidifying the droplets in the droplet pattern to retain the particulates in the droplets.

8. The method of claim 4 wherein, the step of solidifying the droplets in the droplet pattern further comprises the step of curing the droplets.

9. A polishing surface on a polishing pad comprising: successive layers of droplets of material, the droplets being arranged in a pattern of solidified droplets in each of the layers, and a surface texture of the polishing surface provided by recesses bounded by the droplets arranged in the pattern of droplets.

10. A system for making a polishing surface on a polishing pad comprising: a reservoir supplying solidifiable material of fluid phase to a computer controlled piezoelectric printer, a printer head of the printer dispensing droplets of the material in a pattern of droplets onto a substrate of a polishing pad, and a curing apparatus curing the droplets to solid phase to retain the droplets in the pattern.

* * * * *