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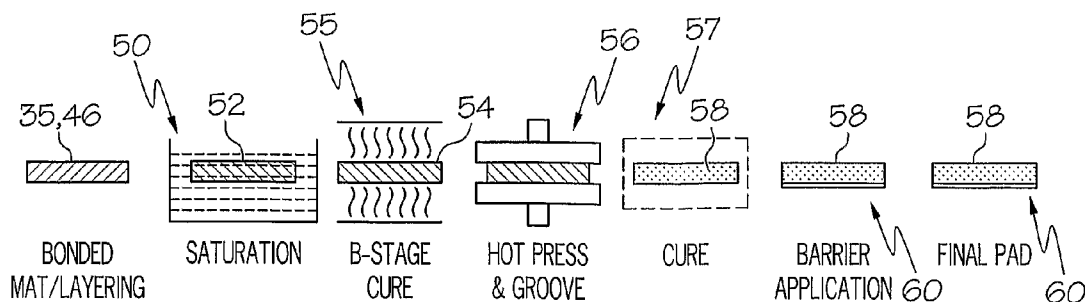
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(54) Title: NONWOVEN POLISHING PADS FOR CHEMICAL MECHANICAL POLISHING



(57) Abstract: A polishing article and its use as a polishing article for various substrates, especially for polishing a semiconductor wafer. The article is comprised of a mesh of splittable intermingled fibers and a binder material holding the fibers in the mesh. The fibers and binder material provide the polishing pad with an absorptive property that maintains the slurry chemistry and particles near the surface for effective polishing.

NONWOVEN POLISHING PADS FOR CHEMICAL MECHANICAL POLISHINGCross-Reference to Related Application

5 This application claims the benefit of U.S. Provisional Patent Application Serial No.60/704638, filed August 2, 2005, titled "Nonwoven Polishing Pads for Chemical Mechanical Polishing", the disclosure of which is expressly incorporated by reference herein in its entirety.

Background of the Invention

10 The present invention relates to an article or polishing pad used for polishing various substrates, more particularly used for chemical mechanical polishing.

In a Chemical Mechanical Polishing (CMP) process, substrates, mostly silicon wafers are used. Integrated circuits are formed via various levels of the semiconductor manufacturing process. At each level, conductive, semi-conductive
15 and insulating layers are deposited. During this process, the surface of the semiconductor wafer becomes irregular and requires polishing in order to become planar enough to proceed to the next step. Removing the surface irregularities through polishing is often referred to as planarization.

One method used for planarization or polishing is by chemical and mechanical
20 means (hence known as chemical mechanical polishing). The CMP process uses a liquid polishing slurry which generally includes a reactive agent (such as deionized water for oxide polishing) with a reactive catalyzer (such as potassium hydroxide or peroxide) for chemically attacking or weakening a thin layer of the substrate and an abrasive particle (like silicon dioxide) for mechanical removal of the weakened
25 substrate. The substrate is polished when a rotating polishing pad and liquid slurry are brought in contact with the substrate to be polished. The polishing pad itself assists in the CMP process by providing support against the substrate being polished and is also a carrier to bring the slurry in contact with the substrate. The polishing pad has a desired surface texture, modulus of elasticity, and material composition such that it
30 facilitates uniform removal of material from the substrate. The spent liquid slurry is

generally not reclaimed and is discarded; therefore slurry consumption is a significant cost in the polishing process.

Polishing pads may have a transparent window for endpoint detection.

Endpoint detection is a procedure to monitor the dielectric removal rate or the planarization efficiency during the polishing process. A small portion of a pad is generally cut out and this external transparent window is attached. This window helps a laser to pass through the pad and detect the amount of material (for example oxide) removed on the wafer or substrate that is being polished. Once the desired amount of material is removed, the laser detects the endpoint and adds a method of control in the polishing process.

Some of the main consumables in a CMP process are slurry, polishing pads and conditioning disks. Conditioning is a process where the surface of a polishing pad is abraded with an abrasive conditioning disk, so that the surface has a texture (peaks and valleys) to optimize slurry transport and material removal; as well as renew the pad's working surface to prevent glazing. There are various polishing pads available in the market, most of them being polyurethane based pads. These pads require periodic or even continuous conditioning during a polish cycle to prevent glazing.

As a result of conditioning, the polishing pad surface wears. Wearing of the polishing pad is one of the reasons why a polishing pad is discarded after a certain number of polishes, adding to the cost of the process.

Brief Description of the Drawings

FIG 1 is a schematic representation of spunbonding process.

FIG. 2 is a cross sectional representation of a bicomponent fiber.

FIG. 3 is a schematic representation of a hydroentanglement/spunlacing process.

5 FIG. 4 is a schematic representation of a process including the insertion of grooves in a stacked material.

FIG. 5 is a schematic representation of a needlepunching process.

FIG. 6 is a schematic representation of a process of manufacture of a polishing pad.

10 FIG. 7 is a schematic representation of insertion of grooves in a needlepunched material.

FIG. 8 is a schematic representation of a window area in a pad for endpoint detection.

Summary of the Invention

In one embodiment of the present invention, there is provided a nonwoven polishing pad with a mesh of various polymeric fibers.

5 In one aspect of one embodiment of the present invention, there is a nonwoven polishing pad that is spunbond, spunlaced and subsequently needlepunched to form a thick mat suitable for CMP pad manufacture.

In another aspect of one embodiment of the present invention, there is a nonwoven polishing pad that uses splittable bicomponent or multicomponent fibers. In a further refinement of this aspect the fibers are sponbond into a web.

10 In another aspect of one embodiment of the present invention, the nonwoven web is bonded via hydroentangling/spunlacing.

In another aspect of one embodiment of the present invention, the nonwoven web is needlepunched.

15 In another aspect of one embodiment of the present invention, there is a nonwoven polishing pad that includes at least some portion which is transparent defining a window. The window is preferably an intrinsic part of the pad itself. The window is preferably created by melting and molding the polymer mat in a window area.

20 In another embodiment of the present invention, there is a nonwoven polishing pad that is manufactured via resin saturation and cure processes.

In one aspect of one embodiment of the present invention, the saturation can be carried out by one or more of the following: absorption, immersion, coating, impregnation, roller or spray deposition, stir casting, and the like.

25 In another embodiment of the present invention, there is a polishing pad that can have a texture or grooves imparted via hot-pressing, molding, calendaring, machining or embossing rollers.

Detailed Description of the Drawings and the Preferred Embodiments

A pad preferably minimizes the amount of polishing slurry required, while polishing the substrate at the desired material removal rate, planarity, uniformity, and with minimal defects. Similarly, a polishing pad that requires less conditioning is preferred due to extended pad and conditioning disk life. The fibers and binder material provide the polishing pad with an absorptive property that maintains the slurry chemistry and particles near the surface for effective polishing.

According to one embodiment of the present invention, a nonwoven poromeric polishing pad is provided. In one aspect of the invention, this pad or article is made of a mesh of fibers and/or filaments and is impregnated with thermoset resins. The thermoset resins, or binder materials, are preferably coalesced among the fibers or filaments to leave pores in the interstices between the fibers or filaments of the mesh. The fiber or filament nonwoven mat is preferably a spunbond mat of thermoplastic bicomponent or multicomponent fibers. The fibers or filaments may include, but are not limited to, synthetic polymer fibers like polyester, polyamides, polyethylene, acrylic, polypropylene, polyurethane, vinyl chloride polymers, polycarbonates, and combinations and copolymers of the above mentioned fibers. It should be understood that other fibers or filaments known to those of ordinary skill in the art are contemplated as within the scope of the invention.

The nonwoven web suitable for use in the pad of the invention includes, but is not limited to spunbonded in which fibers are spun from granulates and directly dispersed to form a web that is subsequently thermally bonded, melt-blown in which high-velocity air blows a molten polymer from an extruder die tip onto a conveyor or takeup screen to form a fine fibrous and self-bonding web, airlaid in which staple fibers, pulp, powder, or other components are dispersed via air into the web, wet-laid in which the fibers are separated by water and laid on a circulating screen belt on which the water is drained off, carded in which staple fibers are made into a web in a carding machine fitted with rotating rollers, or stitchbonded construction.

As illustrated in FIG. 1, the preferred nonwoven web is of a spunbond construction having splittable bicomponent or multicomponent fibers or filaments. A spunbonding apparatus 10 includes an extruder 11 which receives a raw material,

typically granulated or pelletized polymer, which melts the polymer material, and which produces an extrusion of the raw material. One or more extruders 11 may be used to create individual fibers which are formed into multi-component fibers. The extrusion passes through a metered pump 12 which is coupled to a spinneret 14. The extrusion is received by the spinneret 14, which forms multiple unitary fibers 15. The multiple unitary fibers, which are hot, are then exposed to cold air provided by a cold air device 16 to cool the fibers when exiting the spinneret 14.

The fibers 15, after being partially cooled, are subjected to compressed air provided by a compressed air device 18. The multi-component fiber or fibers are received and pass through an attenuator 20, having an output 22. The attenuator stretches the multi-component fiber to thereby align the polymer chains. The output 22 deposits the multi-component fibers on a traveling belt 24, having apertures, under which is disposed a suction device 26 which holds the multi-component fibers to the belt 24.

The individual fibers or polymer filaments of the multi-component fibers preferably vary in denier in the range of 0.5 dpf to 4 dpf. The bicomponent or multicomponent construction can be a side by side (two different polymers extruded side-by-side to form a single filament), sheath-core (two different polymer components where one of the component (core) is fully surrounded by the second component (sheath)), island-in-sea (each filament includes multiple continuous polymer strands (islands) in a sea of dissolvable polymer matrix), a segmented pie (each filament contains two or more different polymers alternating in segments), as illustrated in FIG. 2, each segmented pie having typically 4, 8, 16 or 32 segments, trilobal or a version or combination thereof.

The spunbond web then preferably proceeds to a hydroentanglement/spunlacing apparatus 30 as illustrated in FIG. 3 where the web of multi-component fibers is bonded or entangled. The fibers are received from the spunbonding apparatus 10 and placed on a moving belt 32 which passes beneath a water jet device 34. One preferred method of bonding or entanglement is by use of high pressure water jets, however it should be understood that other methods of bonding or entanglement known to those of ordinary skill in the art are contemplated as within the scope of the invention. This process of using high pressure water jets is

referred to as spunlacing or hydroentanglement. The water-jet pressure can be as high as 200 bar with forming wire of 60 to 100 mesh. The present invention is not, however, limited to these values.

5 The spunbond web of splittable bicomponent fibers is passed through the high pressure water jets provided by the water jet apparatus 34. There can be multiple water jet apparatus using different water jet pressures entangling the web from a front and/or back side. The water jet pressure imparts high force on the bicomponent or multicomponent fibers. This process results in splitting of the bicomponent or multi-
10 component fibers into fine individual fibers intertwined within each other. The resulting mat or fabric has micron size diameter fibers or filaments in its construction. One example of a mat or fabric that is manufactured using this process is Evolon® by Freudenberg® US Patent number 5,899,785, the contents of which are incorporated herein by reference. It should be understood that other methods known to those of skilled in the art that use chemical, solvent or thermal means to split or separate
15 individual fibers can also be used.

This splittable fiber spunbond spunlaced fabric is used for manufacture of the nonwoven poromeric polishing pad. As illustrated in FIG. 4, this fabric is made into a precursor mat of desired thickness by stacking multiple layers 35 of the fabric that is resin saturated and partially cured. The number of layers of fabric used to make a pad
20 is preferably between 2 and 15, and more preferably between 5 and 12 and even more preferably between 6 and 9; depending on thickness capability of the spunbond/spunlace process. The stacked layers of fabric 35 are placed in a heat press 36. The heat press 36 includes a die having a plurality of protrusions 38. The press 36 is pressed into the multiple layers 35 which bonds the multiple layers together
25 through the action of applied heat. The press 36 forms a plurality of grooves 40 in the resulting mat 41. The grooves 36 extend into the mat 41 a distance dependent on the length of the protrusions 38 and the amount of compression applied by the press 36. The length of the protrusions 38, and therefore the depth of the resulting grooves, is selected to form a pad having multiple layers which maintains its integrity during use.
30 Other alternative methods of forming a pad from multiple layers are within the scope of the present invention and include embossing.

In an alternative embodiment as illustrated in FIG. 5, the mat of stacked spunbond spunlaced layers 35 are passed through a needlepunching device 42 which includes a bed of mechanical needles 44. The mat 35 after being needlepunched, exits the needlepunching device 42 as a bonded mat 46. This process is referred to as
5 needlepunching. The layers of the nonwoven mat 35 are bonded during the needlepunching process as a result of entanglement of fibers in the z-direction (illustrated as being in a vertical direction) during the process. The resulting nonwoven mat 46 can be washed, chemically treated, and/or vacuumed before subsequent resin saturation steps.

10 It is contemplated as within the scope of the invention that a number of different resins might be used for the manufacture of one or more embodiments of the polishing pads of the present invention. One preferred resin is a thermoset resin such as epoxy resin. Other resins that might be used include, but are not limited to, modified epoxy, phenolic, silicone, urethane resins, ethylenically unsaturated
15 material, acrylated urethane resins, acrylated epoxy resins, α,β -unsaturated carbonyl groups, and combinations thereof can be used. Thermoplastic and UV cured resins can also be used as a binder in the nonwoven mat. The resin used can be a self-curing resin or a catalyst cured resin. The amount of resin impregnated in the stacked nonwoven mat is controlled so that the final pad results in optimal porosity, stiffness,
20 and strength.

In one alternative to the needlepunch process, it is contemplated that one or more embodiments of the present invention might include nonwoven porous mats formed by stacking the fabric 35 then resin saturating and partially curing the resin, and subsequently curing and bonding the layers under heat and pressure to get the
25 desired thickness of the pad.

To manufacture the pads of this invention, once the needle punched mat 46 or stacked mat 35 is complete, the mat 35 or 46 can be impregnated with a liquid resin as illustrated in FIG. 6. The saturation process preferably comprises of impregnation of the fiber mat or layers with a liquid resin and subsequently curing the resin resulting
30 in a resin matrix. The mat 46 or 35 can be impregnated with a liquid resin by saturating the mat 46 or 35 in a tank 50 of resin 52. It should be understood that the saturation process can be carried out via immersion, roll, or spray deposition of resin

or like methods known to those of skill in the art. One preferred method of manufacture is immersion saturation of the nonwoven porous mat, or stack of nonwoven porous fabric, with epoxy resin. After saturation, a B-stage mat 54 is partially cured (B-Stage cure) in a curing device 55 as is known by those skilled in the art. At this partially cured state, the mat is heated to the extent such that the resin in the mat is not fully cross-linked and hence the impregnated fabric has some flexibility. The amount of resin and the type of resin can be selected according to the pad requirement to achieve the desired flexibility of the pad (i.e. the hardness or softness of a pad can be changed by modifying the amount, type and mix of resin or varying the processing parameters).

The B-staged mat 54 is then generally blanked into pad form (a circle of desired radius) then compressed to the desired density in a hot press device 56. A groove pattern or embossed surface may also be pressed into the surface of the needlepunched mat 46 during this process as illustrated in FIG. 7. In this case, grooves are heat pressed into the mat after being needlepunched, as opposed to being heat pressed into the mat before being needlepunched as illustrated in FIG. 4. The shape and pattern of grooves can vary depending on the slurry flow requirements.

After a passing through the hot press device 56, the mat 54 is finally cured to a final fully crosslinked desired state in a cure device 57, which applies heat to the mat 54 to form a finally cured mat 58, as would be understood by those skilled in the art. After the final curing, a barrier 60, or backing, is applied to a surface of the mat 58. An alternative arrangement to attaching the pad to the polishing platen is the use of hook and loop structure (hook-a-pile fastener) as described in U.S. Patent No. 6,964,601 from Raybestos. A complete pad 62 results.

In one alternative to the saturation process, the bonded mat 46 nonwoven precursor may contain low melt binder fibers that can be thermally bonded within the matrices to form a pad. For instance, the low melt binder fibers can be made as part of the fiber as illustrated in FIG. 2. In addition, a mat 46 having a multi-component fiber can be formed without the unitary fiber of low melt or dissolvable polymer, but can have low melt binder fibers that are added to the composite fibers exiting the output 22 of the attenuator 20.

Various embodiments of the present invention can include one or more additional processing steps. As illustrated in FIG. 8, for example, a step that can be included in this process or as a subsequent step is the application of heat to a selected area of the mat 58 at a high temperature (>250 F) to form a transparent "window" area that can be used for endpoint detection.

The mat 58 is placed in a heat press mold 64 which includes a first portion 66 and a second portion 68 of the mold 64. The first portion and second portions 66, 68 are moved into contact with and apply heat to an end portion 70 of the mat 58 to form a window 72. The first portion and second portion 66, 68 move into contact with a spacer or shim device 74 which controls the contact of the first and second portions 66, 68 with the mat 58. In a preferred embodiment, the first and second portions 66, 68 apply heat to the end portion 70 to form the window but do not significantly compress the portions of the mat which can be adjacent to the window 72. The window 72 is preferably formed such that a surface 76 of the window 72 is substantially planar with an adjacent surface 78 of the pad 58.

The selected area 70 need not be located at an absolute end of the mat 58, but can be spaced a distance therefrom. The mold 64 provides sufficient heat as well as pressure to form the window 72. The high temperature under pressure causes the fibers and resin of the mat 58 to melt and mold in such a manner that a transparent, high density and fairly rigid area is formed as illustrated in Fig 8. The advantage of such a window is that the materials within the window, and therefore the window 70 itself, are formed as an intrinsic part of the mat 54 and ultimately the finished polishing pad and not externally attached, thereby eliminating the common problem of slurry leakage around the window.

The compressed pad is then preferably cured at the cure temperatures required to cure the resin. The resin is preferably selected in such a manner that its cure temperature is not high enough to degrade the fiber or filament mesh.

In some embodiments of the present invention the cured pad may optionally be passed through a grinder (not shown). The grinder prepares a cured pad to obtain a desirable surface roughness which can be selected according to the type of use the pad undergoes. This process enables the surface of the polishing pad to be uniform/rough in texture and can often reduce pad break-in time.

Various embodiments of the present invention might also include applying a hydrophobic layer to the bottom surface of the cured pad. In some embodiments of the present invention the addition of a hydrophobic layer(s) preferably assists and/or prevents the polishing slurry from wicking through the bottom of the pad and attacking the adhesive layer.

Various embodiments of the present invention might also include applying a double sided adhesive layer on the back of the pad. In some embodiments of the present invention the addition of such an adhesive layer assists in attaching the pad to the polishing platen of a CMP polisher.

As described herein, the pad of the present invention can be made by alternative methods. For instance, layers, of the fabric can be stacked, the stacked mat can then be saturated, passed through the B-stage cure, and hotpressed and grooved. Another method is to stack the layers of fabric, needlepunch the stacked layers of fabric, saturate the needlepunched mat, pass the needlepunched mat through the B-stage cure, and then hotpress and groove the mat. It is also within the scope of the present invention to stack the layers of fabric (which include low melt binder fibers), and then hotpress and groove the layers (which melts the low melt binder fibers).

While the invention has been illustrated and described in detail in the drawings and foregoing description, the same is to be considered as illustrative and not restrictive in character, it being understood that preferred embodiments have been shown and described and that all changes and modifications that come within the spirit of the invention are protected. Accordingly the present invention is intended to embrace all such alternatives, modifications, and variations that fall within the broad scope of the appended claims.

WHAT IS CLAIMED IS:

1. An article comprising:

5 a nonwoven polishing pad including a mesh of polymeric fibers comprising a plurality of composite intermingled fibers, wherein the mesh of polymeric fibers result from being spunbonded and spunlaced.

2. The article of claim 1, wherein the pad comprises a plurality of layers of fabric, the plurality of layers being stacked one upon another.

3. The article of claim 2, wherein the fibers of one layer are intermingled with the fibers of a different layer by needle punching.

10 4. The article of claim 3, wherein the pad is a substantially thick mat suitable for a chemical mechanical polishing pad.

5. The article of claim 1, wherein the pad comprises a transparent window.

6. The article of claim 5, wherein the pad comprises a polymer and wherein the window results from melting a portion of the pad to form the window.

15 7. The article of claim 1, wherein the pad comprises a resin matrix disposed within the pad.

8. The article of claim 7, wherein the resin matrix of the pad is disposed within the pad by saturation.

20 9. The article of claim 8, wherein the resin matrix is disposed within the pad by at least one of absorption, immersion, coating, impregnation, roller disposition, spray disposition, and stir casting processes.

10. An article comprising:

a nonwoven polishing pad including a mesh of polymeric fibers comprising a plurality of composite intermingled fibers, wherein the mesh of polymeric fibers result from being spunbonded and spunlaced and wherein the plurality of composite fibers include a plurality of splittable multicomponent fibers

11. The article of claim 10, wherein a portion of the plurality of splittable multicomponent fibers comprises a low-melt polymer.

12. The article of claim 10, further comprising a web of the composite intermingled fibers resulting from being spunlaced and spunbonded.

13. The article of claim 10, wherein the pad comprises a plurality of layers of fabric, wherein the fibers of one layer are intermingled with the fibers of a different layer by needle punching.

14. The article of claim 10, wherein the pad comprises a transparent window.

15. The article of claim 14, wherein the pad comprises a polymer and wherein the window results from melting a portion of the pad.

16. The article of claim 10, wherein the pad comprises a resin matrix disposed within the pad.

17. The article of claim 16, wherein the resin matrix of the pad is disposed within the pad by saturation.

18. The article of claim 17, wherein the resin matrix is disposed within the pad by at least one of absorption, immersion, coating, impregnation, roller disposition, spray disposition, and stir casting processes.

19. A method of manufacturing a nonwoven polishing article with a mesh of polymeric fibers comprising:

providing a plurality of nonwoven fabric layers, each layer having a spunbonded and spunlaced construction of multicomponent fibers;

5 intermingling the fibers of at least one of the plurality of layers with another of the plurality of layers to form a mat;

impregnating the mat with a resin to form an impregnated mat; and

curing the impregnated mat to form a pad.

10 20. The method of claim 19, wherein the intermingling step comprises needlepunching.

21. The method of claim 19, wherein a portion of the fibers of a layer comprise a low melt polymer capable of being thermally bonded within the matrices of the layer.

22. The method of claim 21, further comprising the step of thermally bonding the portion of the fibers by hotpressing.

15 23. The method of claim 19, further comprising the step of hotpressing the plurality of layers.

24. The method of claim 19, further comprising the step of heating a portion of the pad to form an at least partially transparent window.

20 25. The method of claim 24, further comprising the step of attaching a backing to the pad.

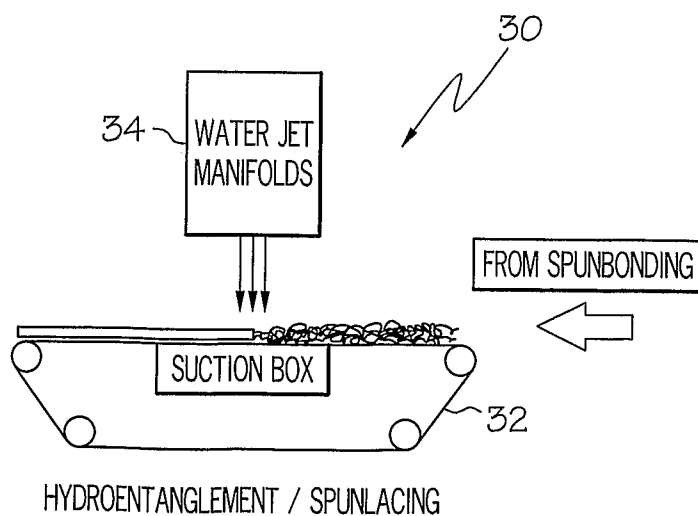
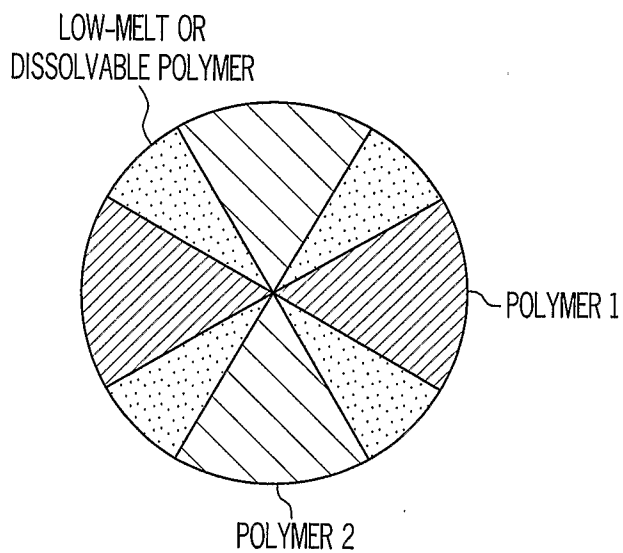
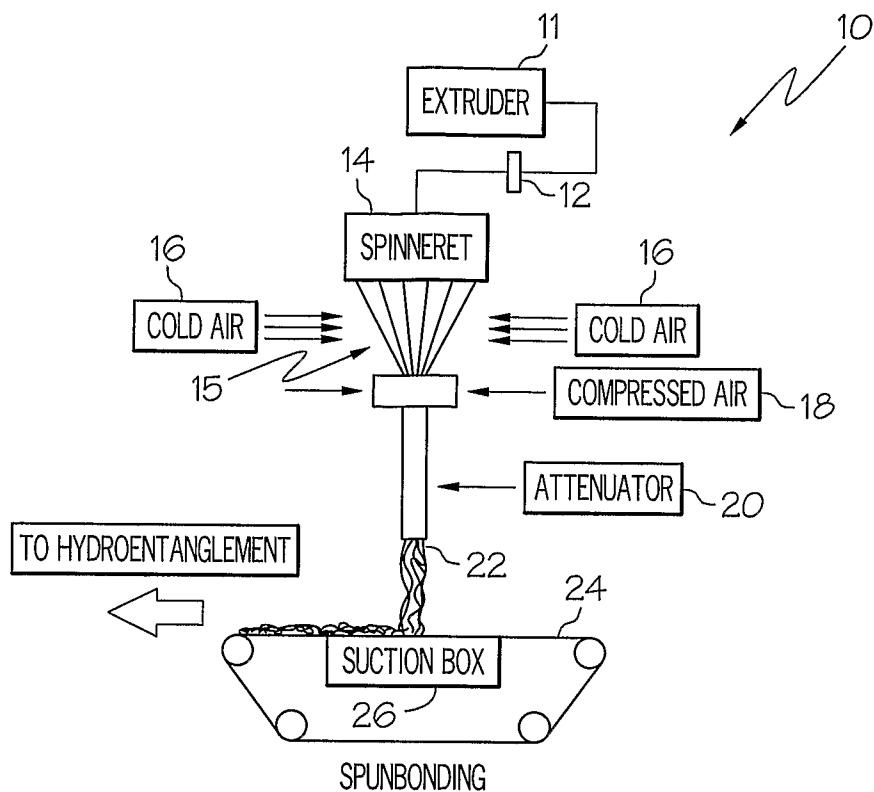
26. The method of claim 25, wherein the attaching step comprises attaching the backing on the pad with a hook and loop structure.

27. The method of claim 19, further comprising the step of forming a surface texture on a surface of the pad by at least one of hot-pressing, molding, calendaring, grinding, machining, or embossing with a roller.

5 28. The method of claim 19, further comprising the step of applying a hydrophobic layer to the back surface of the pad, wherein the pad includes a polishing surface and a back surface.

29. The method of claim 19, further comprising the step of applying a double sided adhesive layer to the back surface of the pad, wherein the pad includes a polishing surface and back surface.

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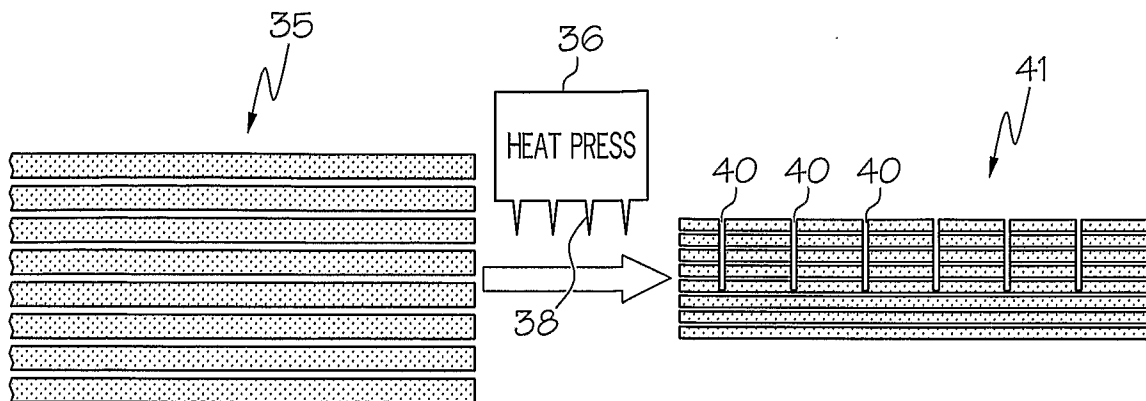


FIG. 4

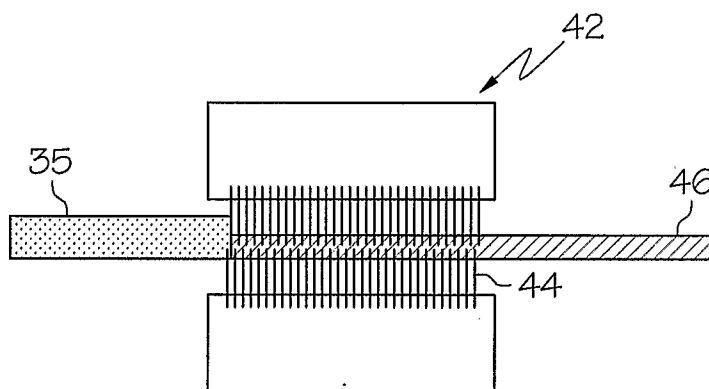


FIG. 5

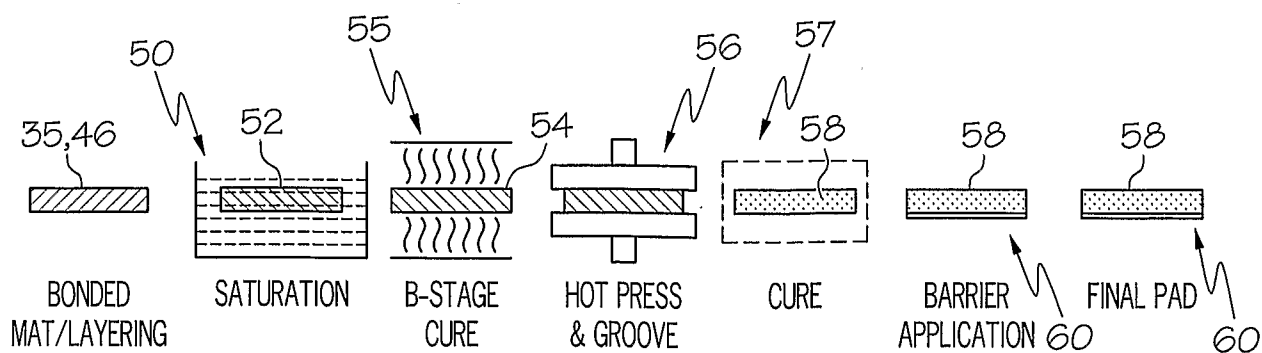


FIG. 6

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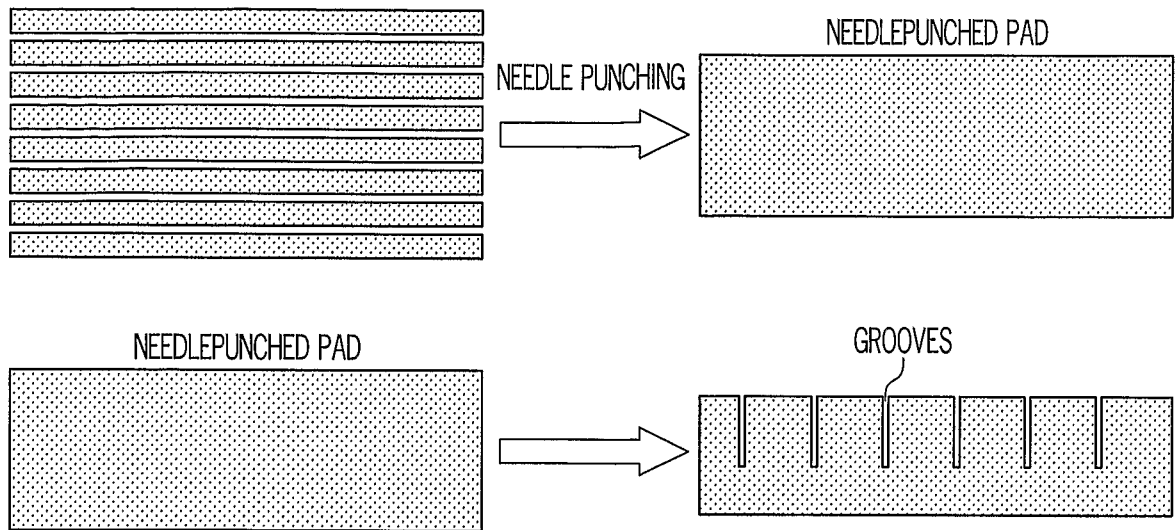


FIG. 7

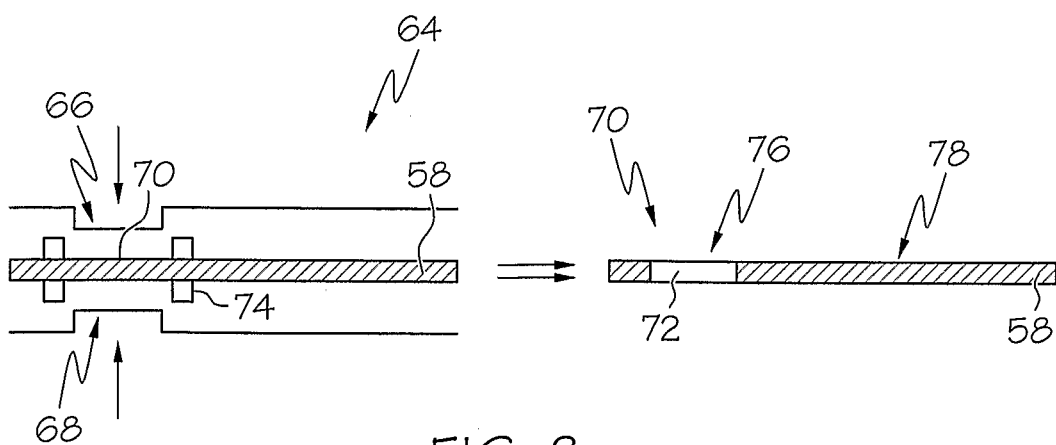


FIG. 8