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STRUBE et al.

(54) **ABSORBENT ARTICLES**

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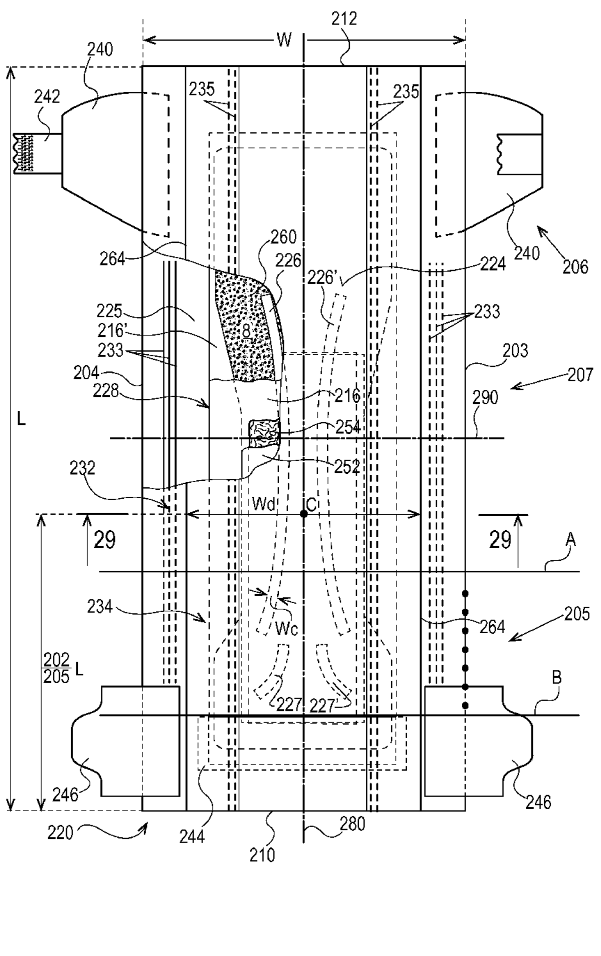
A61F 13/513	(2006.01)

(52) **U.S. Cl.**

CPC ***A61F 13/51104*** (2013.01); ***A61F 13/15203*** (2013.01); ***A61F 13/5116*** (2013.01); ***A61F 13/513*** (2013.01); ***A61F 13/53*** (2013.01); ***A61F 13/534*** (2013.01); ***A61F 13/551*** (2013.01); *A61F 2013/15365* (2013.01); *A61F 2013/51009* (2013.01)

(57) **ABSTRACT**

Absorbent articles having airfelt-free cores or substantially airfelt-free cores in combination with high loft, three-dimensional nonwoven materials are disclosed herein. Packages comprising these articles are also disclosed.



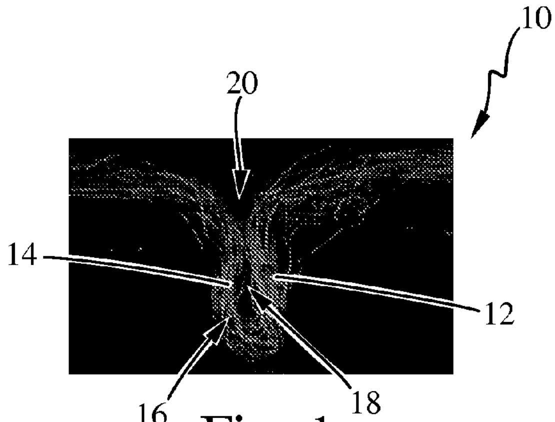


Fig. 1
PRIOR ART

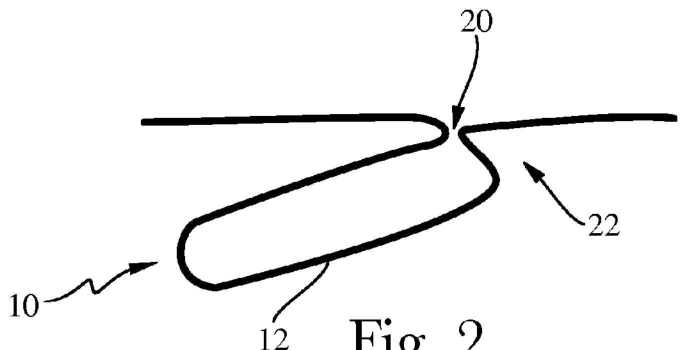


Fig. 2
PRIOR ART

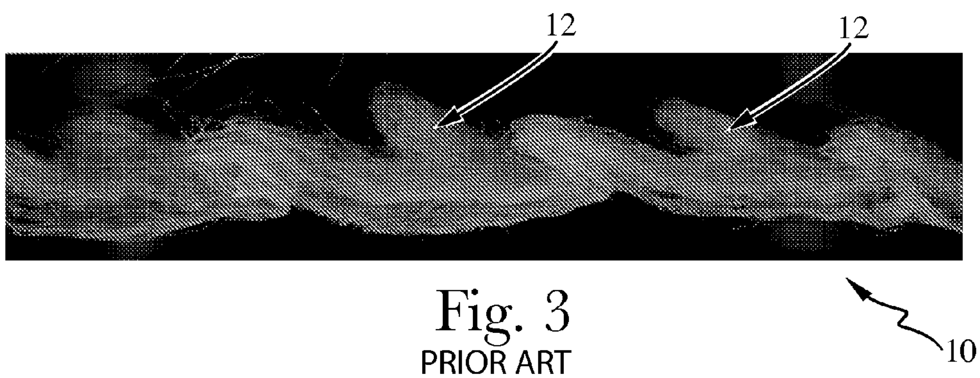


Fig. 3
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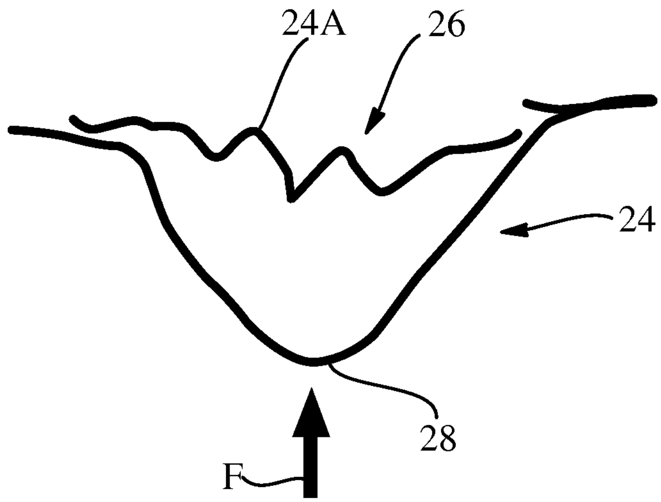


Fig. 4

PRIOR ART

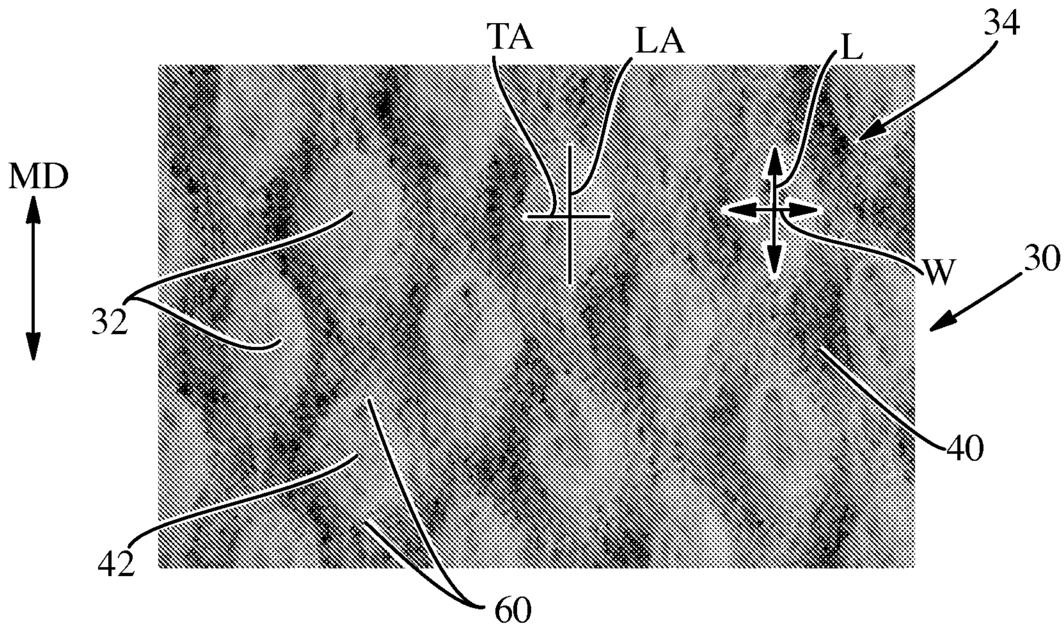


Fig. 5

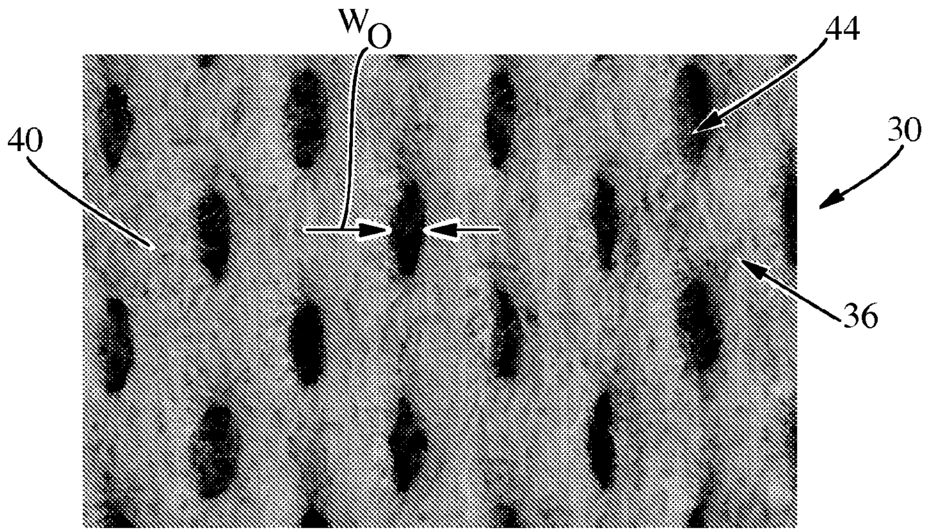
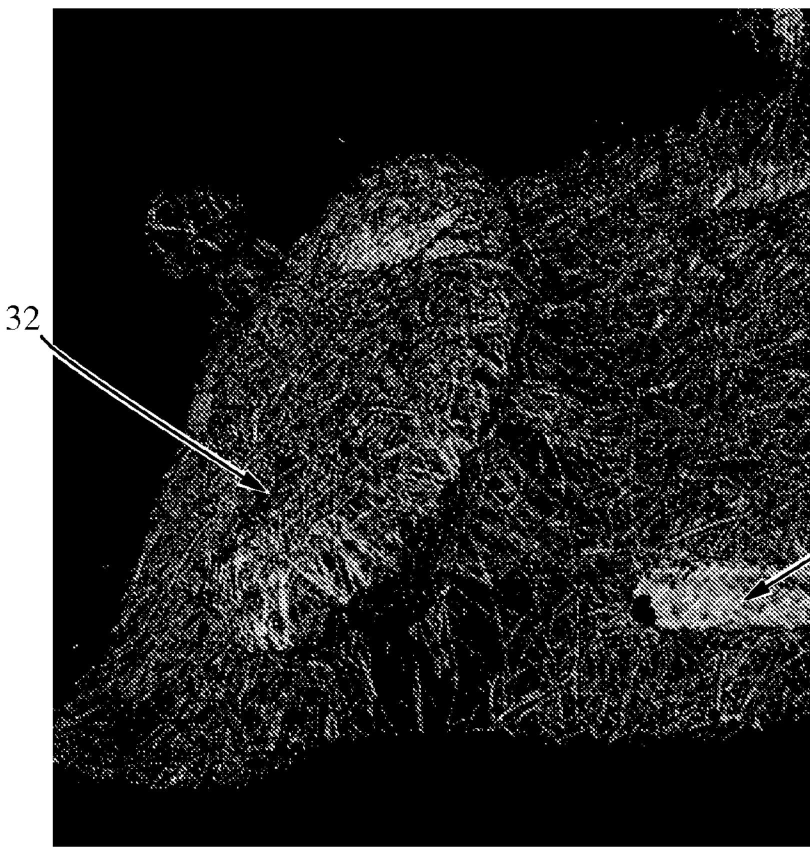


Fig. 6



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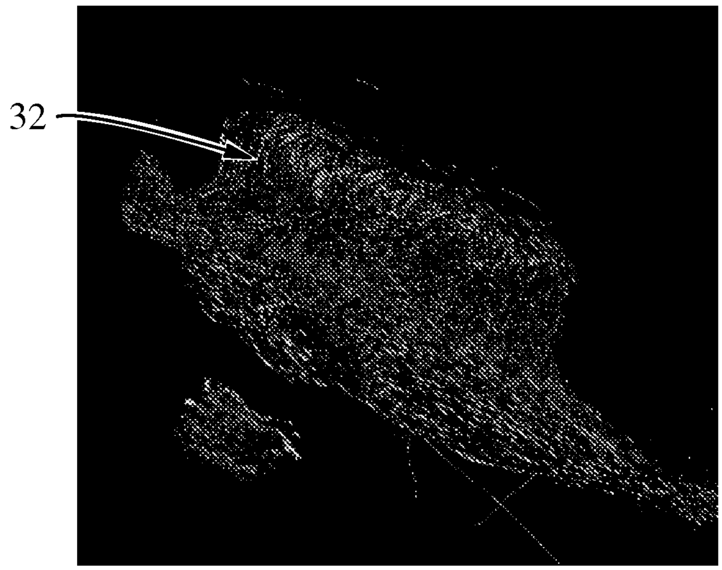

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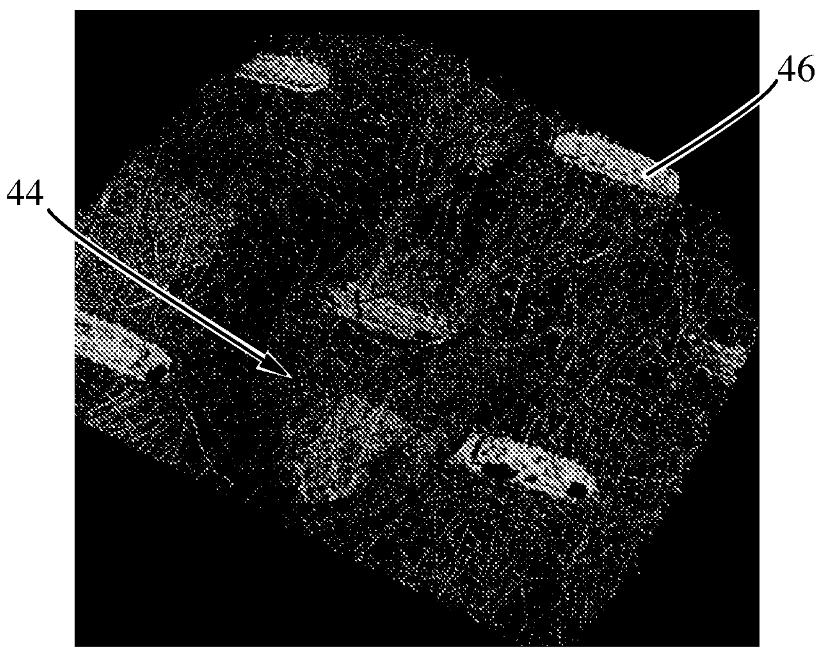
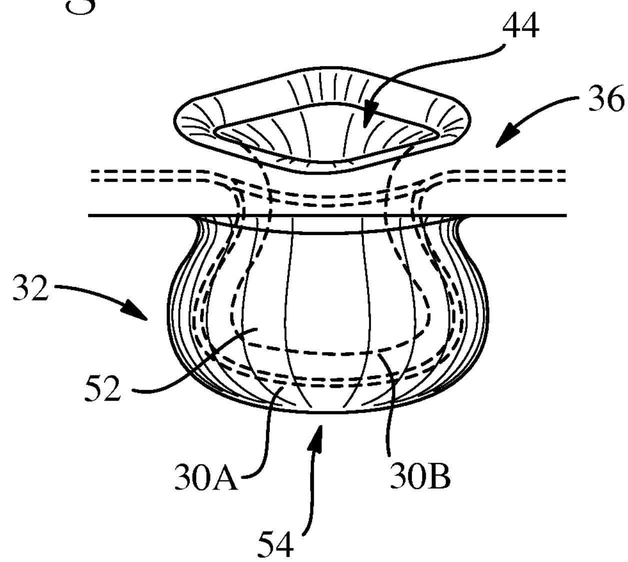


Fig. 9

Fig. 10



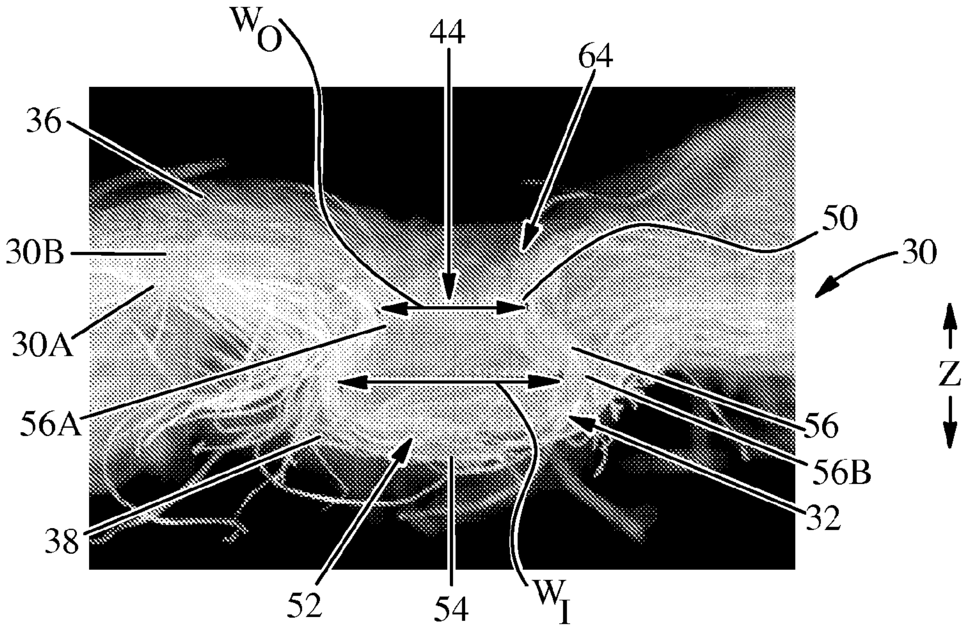


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Fig. 11

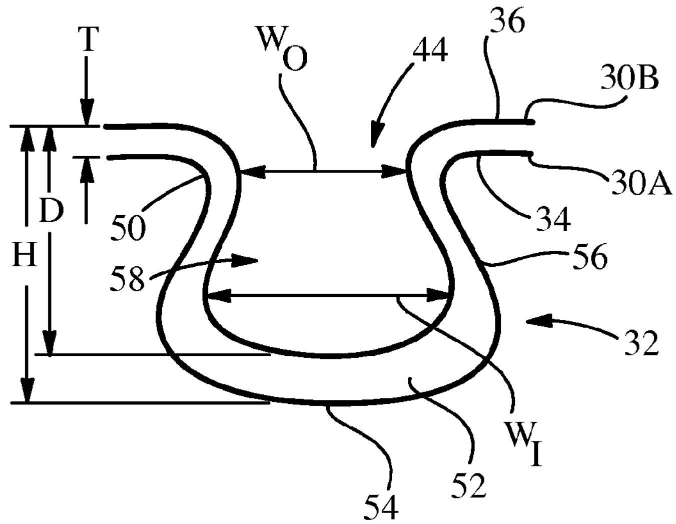

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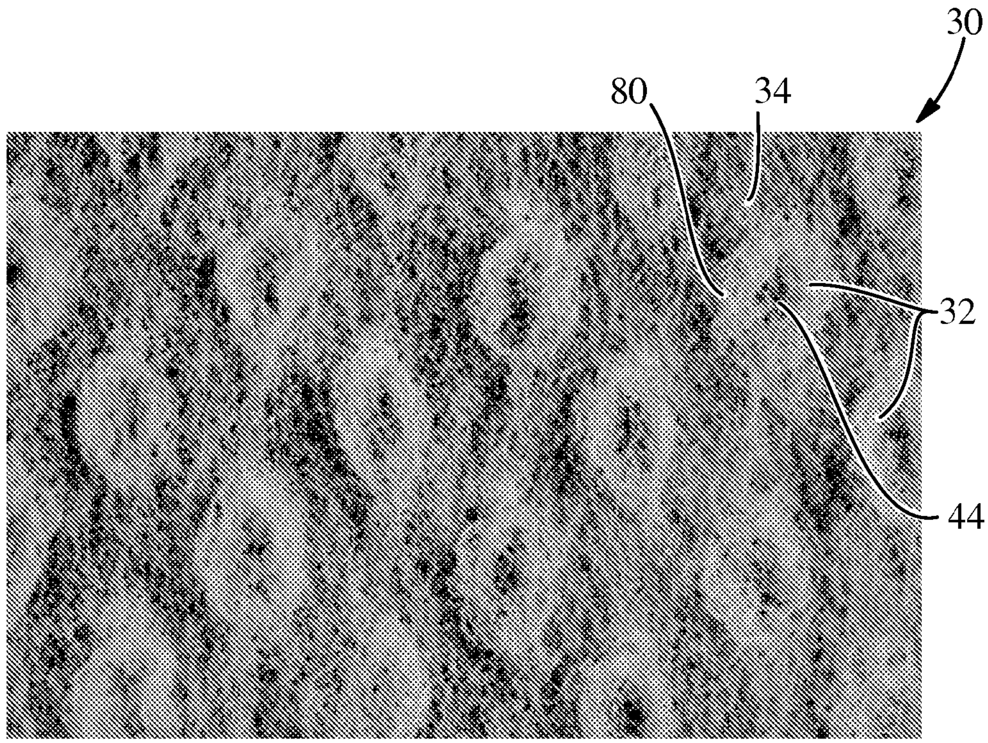
Fig. 12



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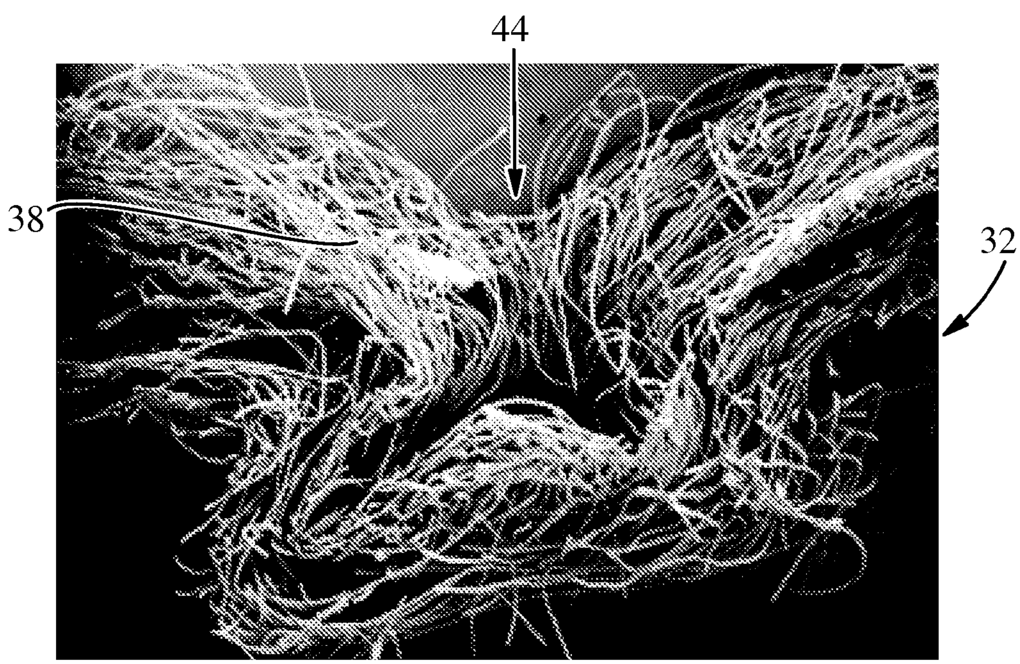

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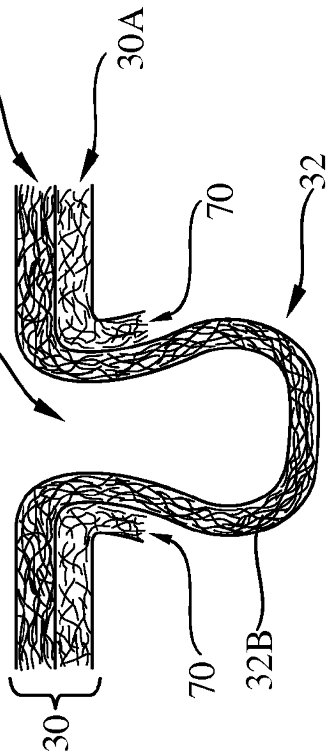

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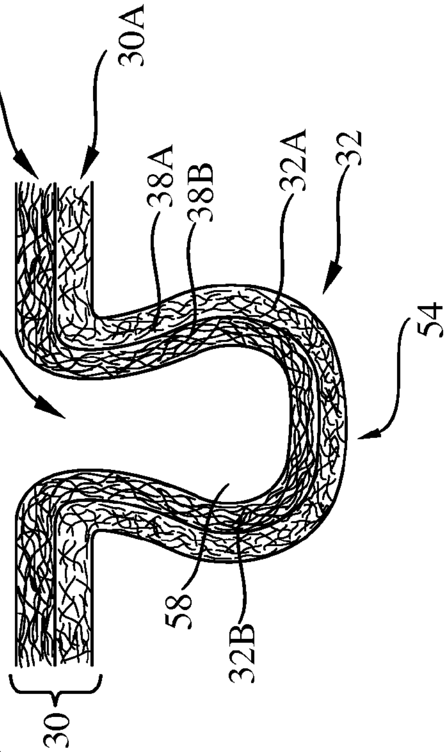
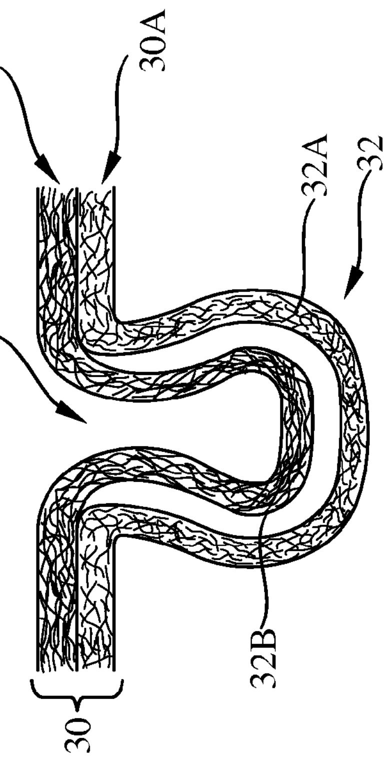


Fig. 15A



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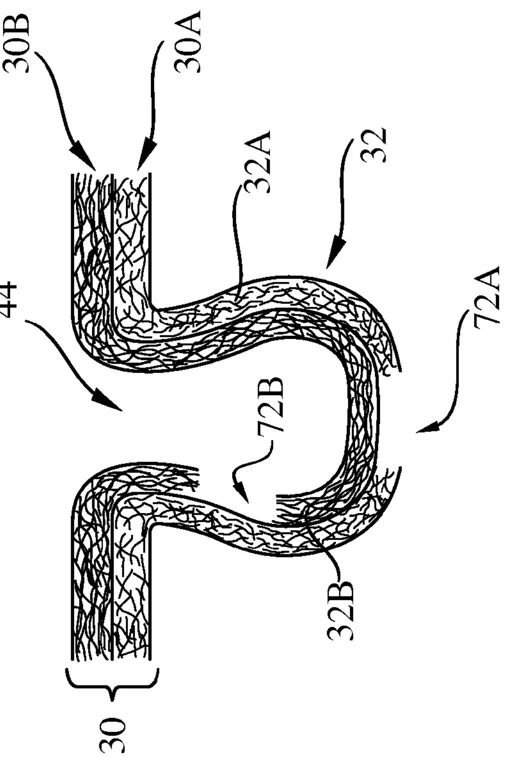

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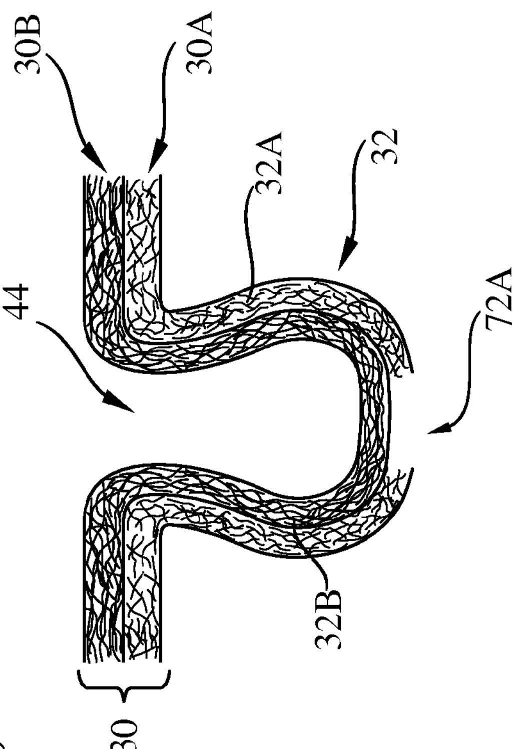

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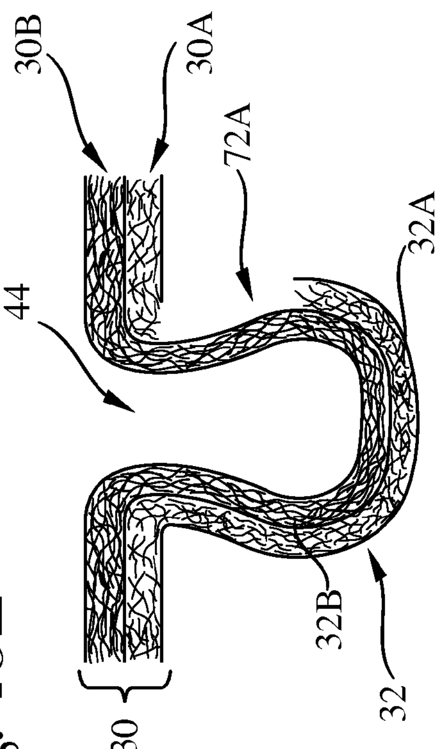

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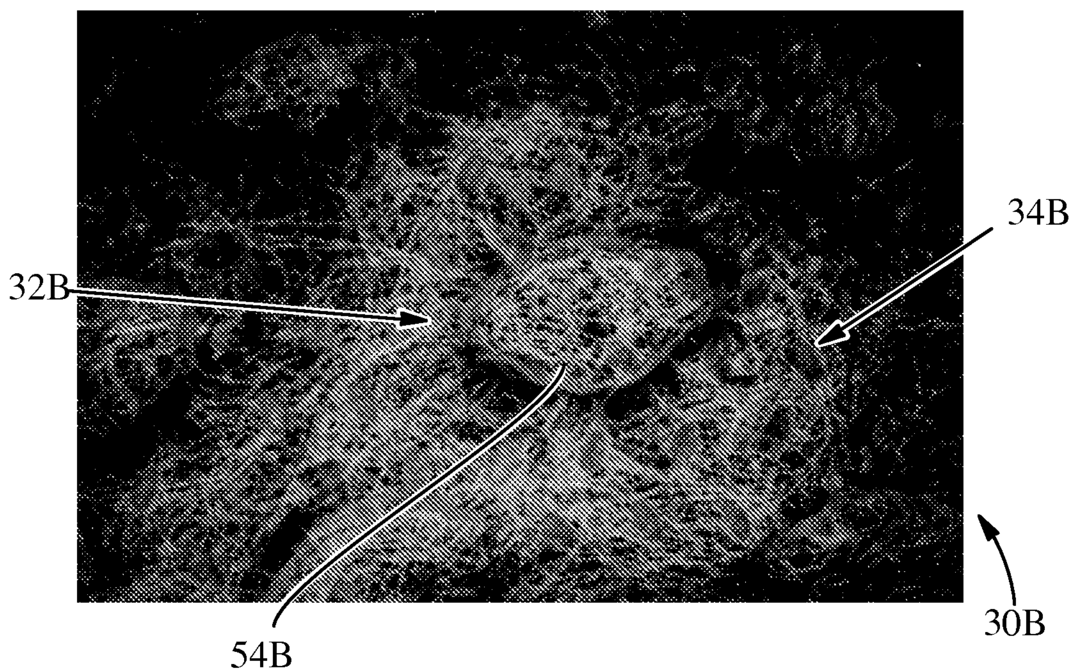

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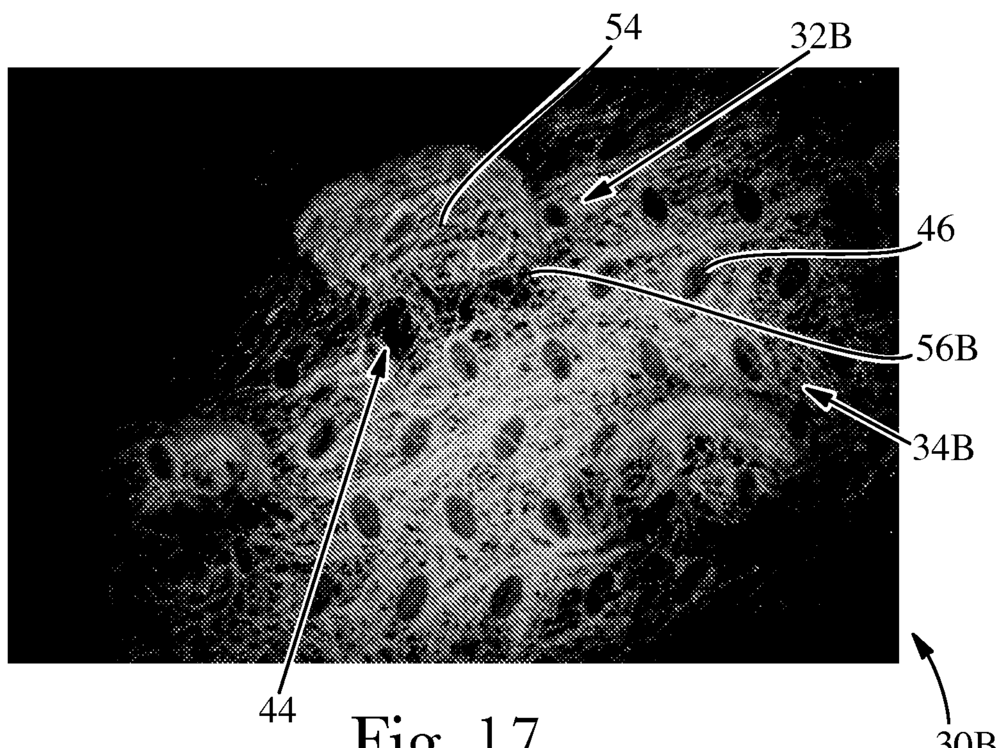

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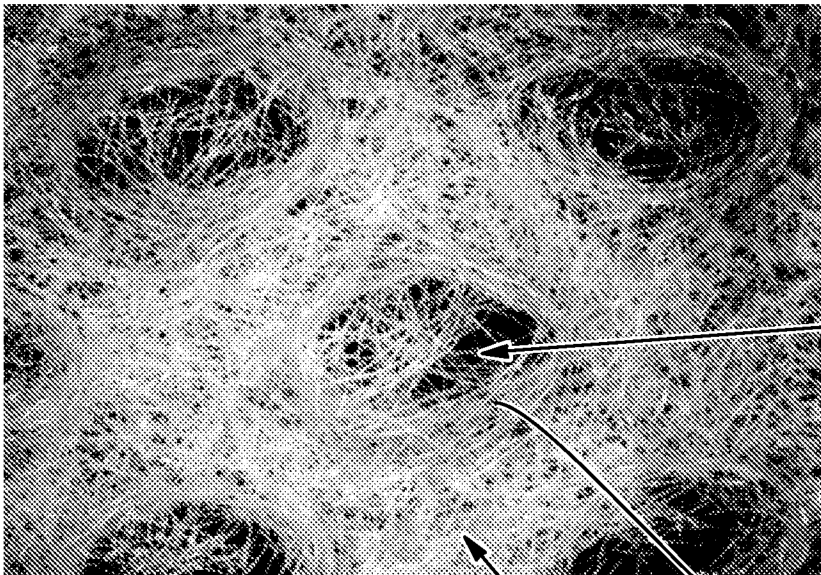

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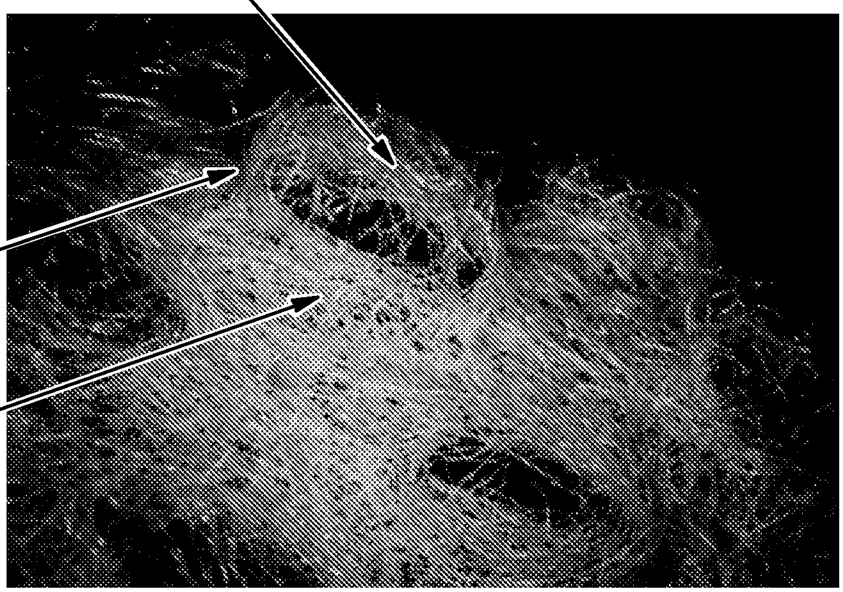

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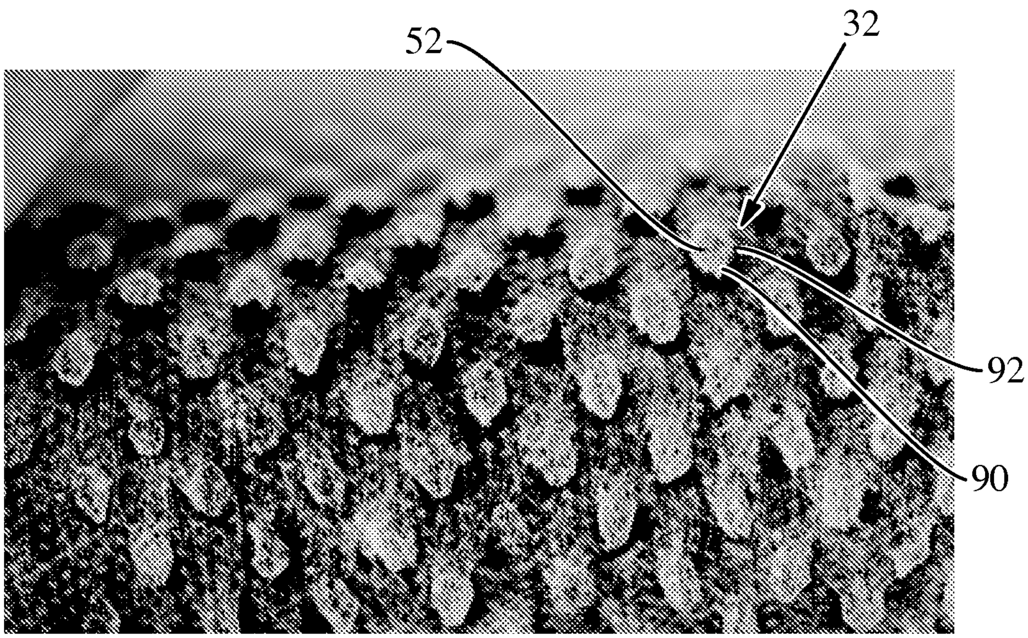

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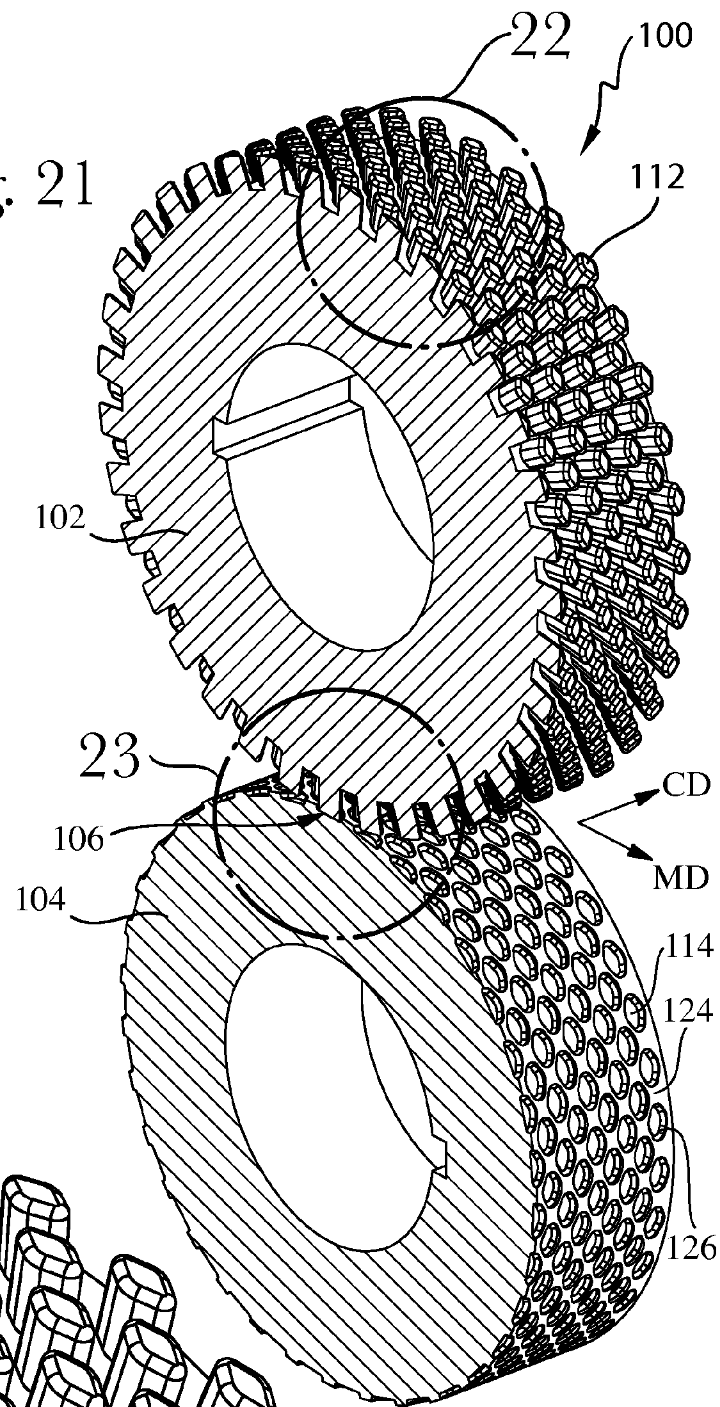
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Fig. 21

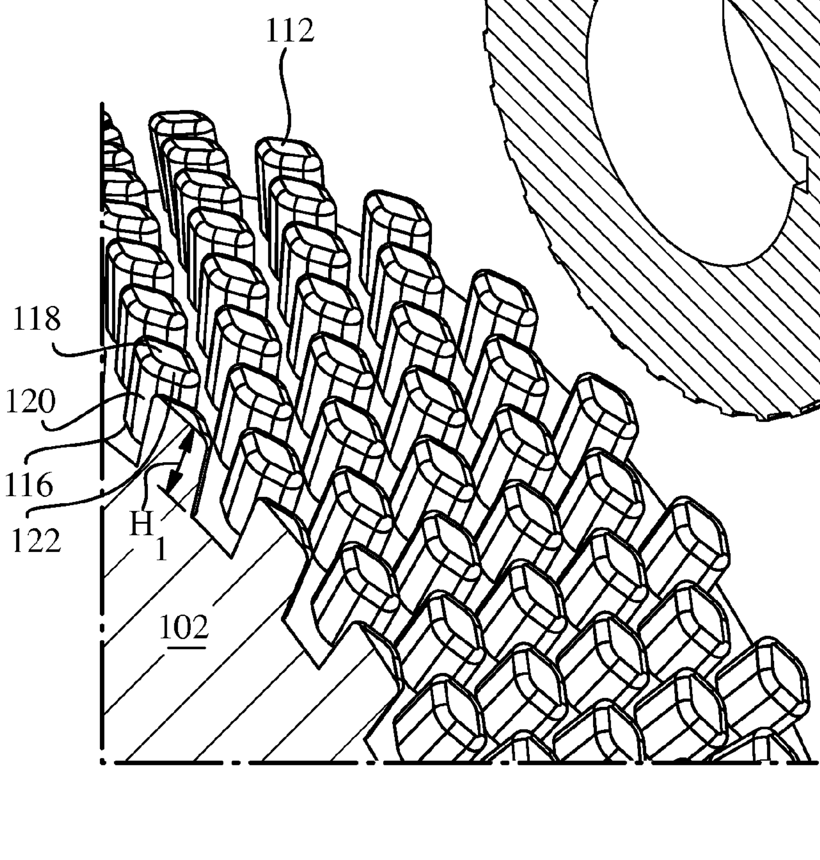
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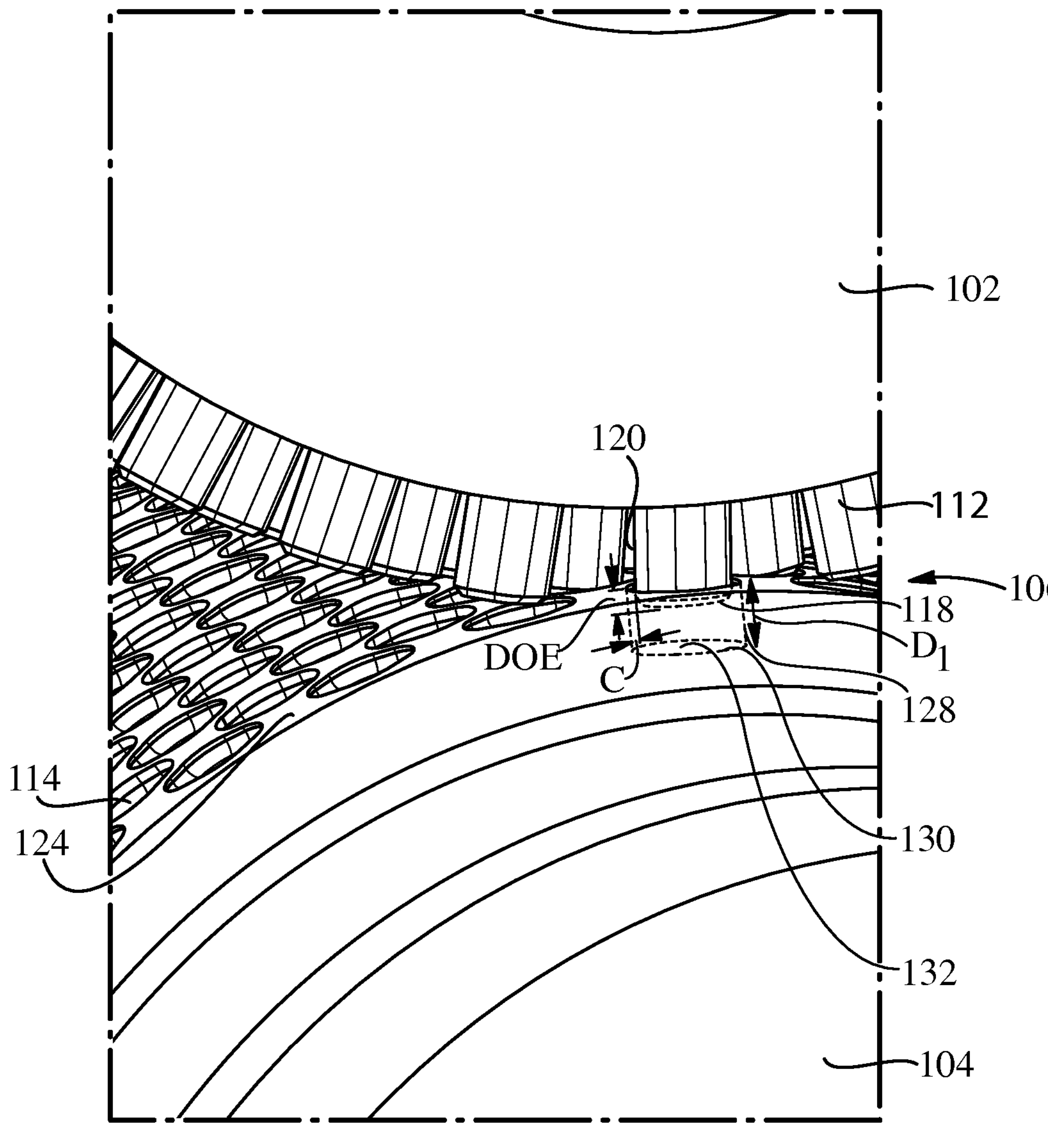
Fig. 22



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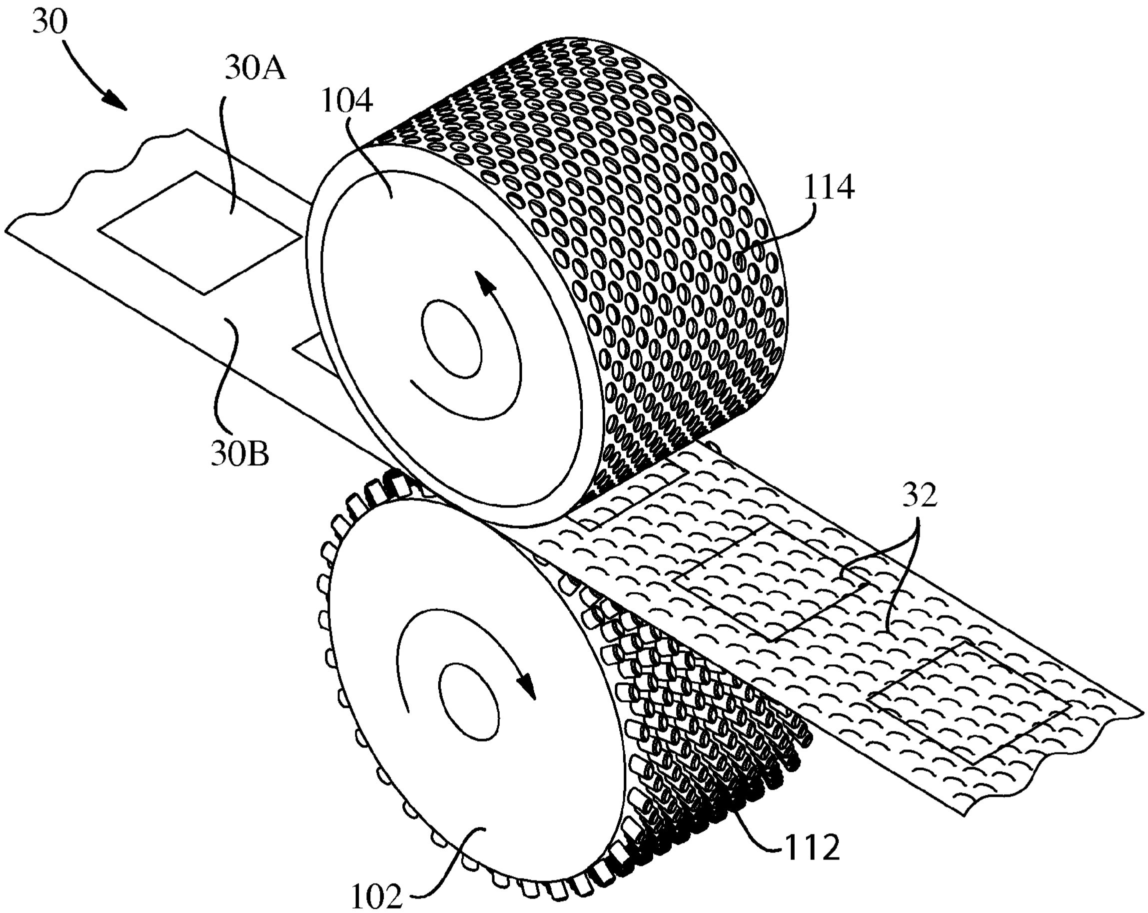
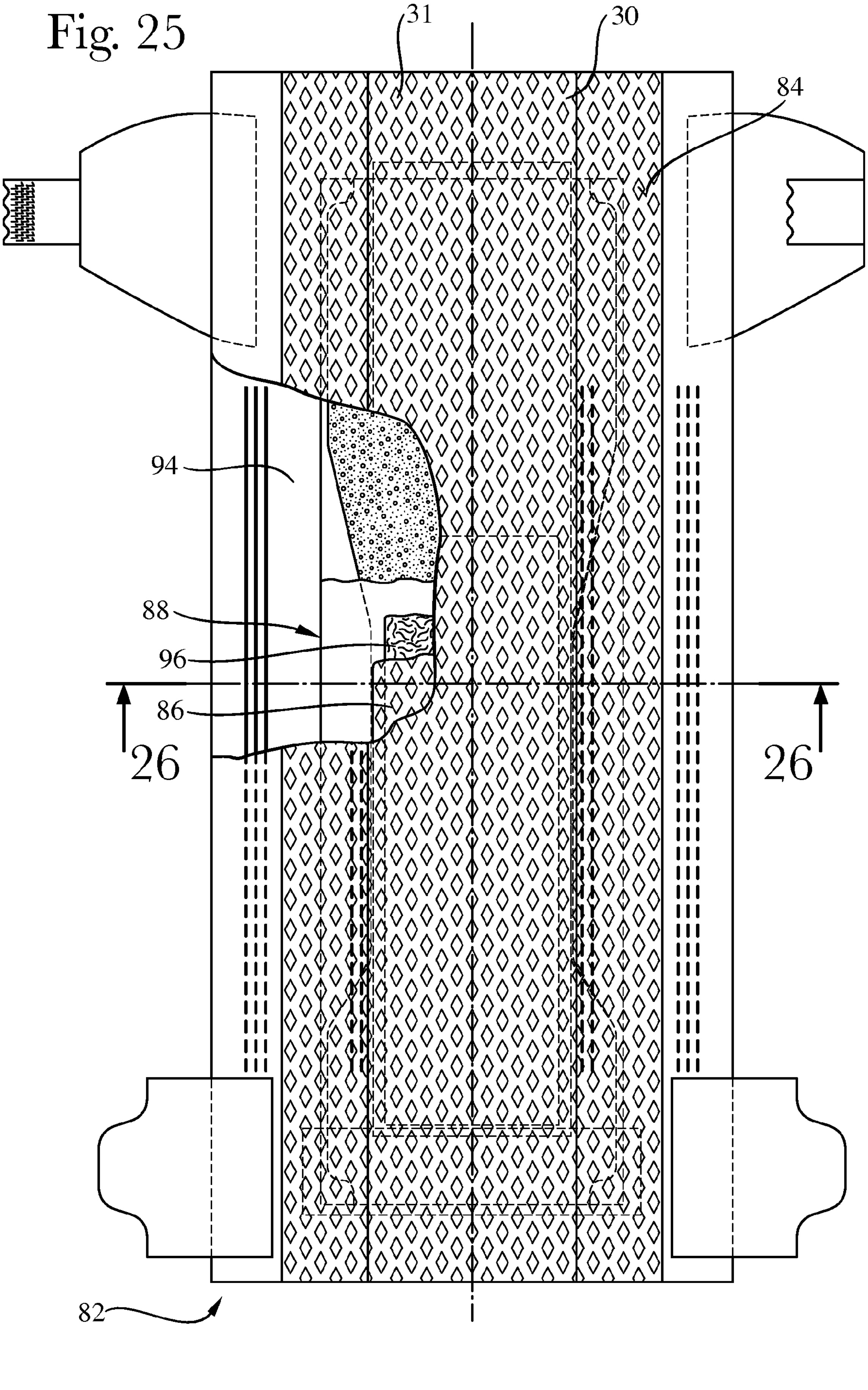
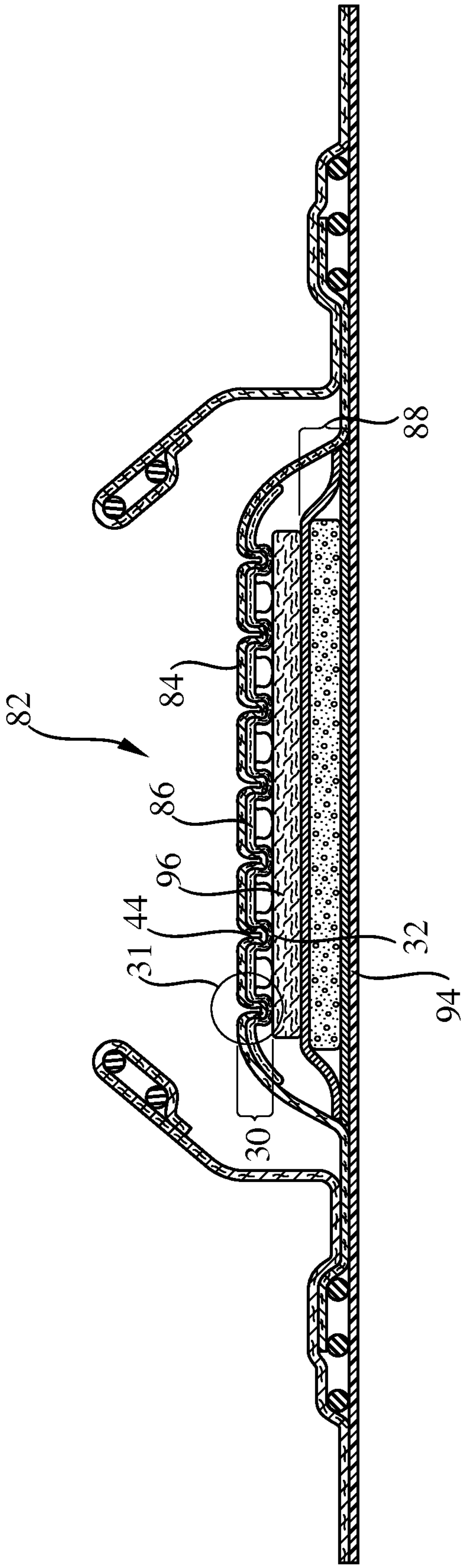


Fig. 24

Fig. 25





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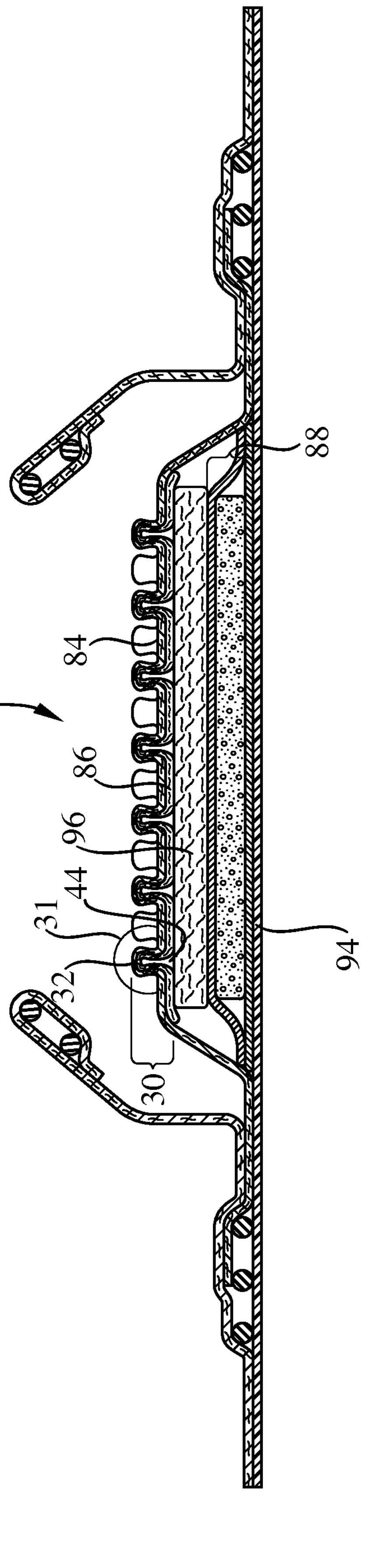

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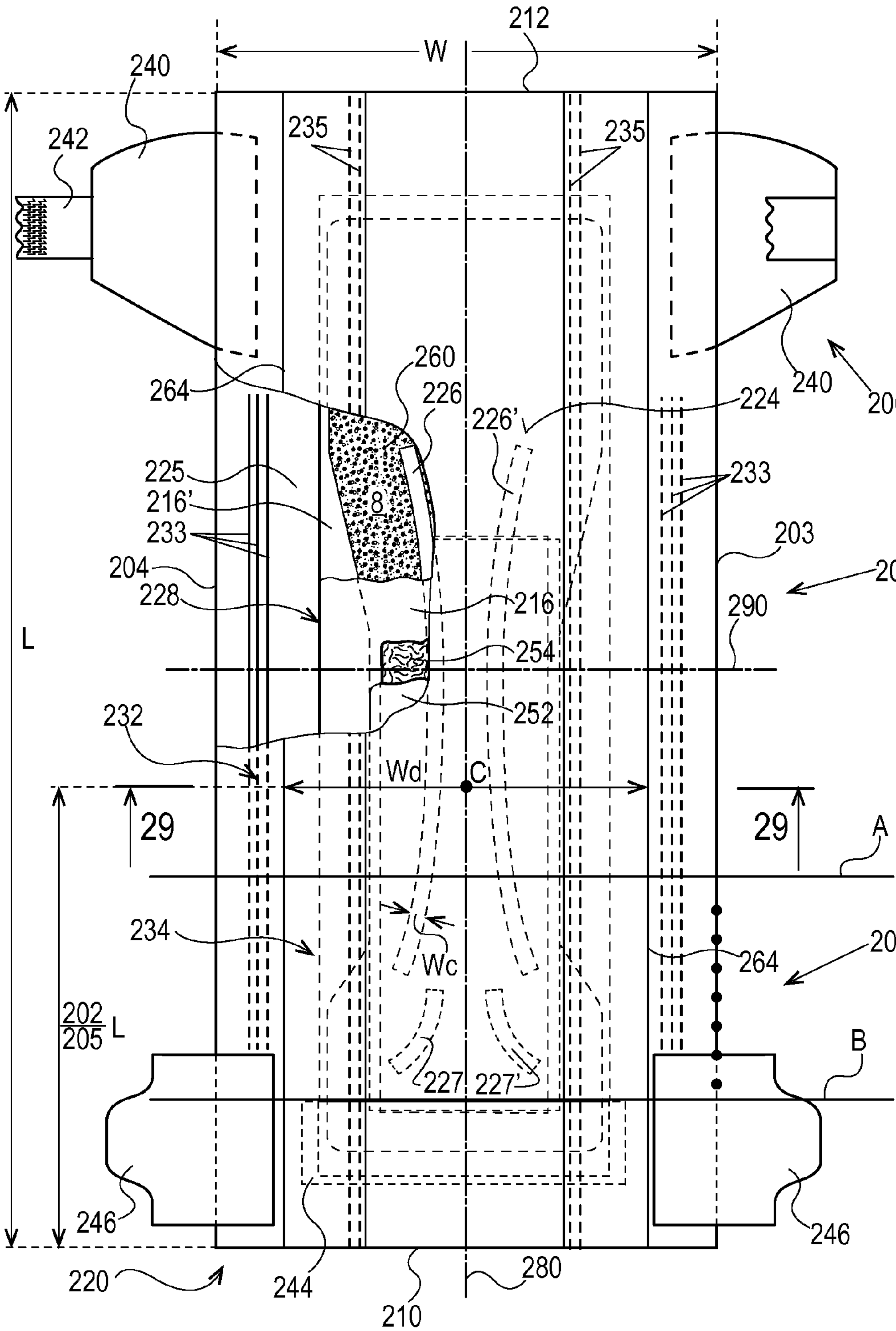
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Fig. 28

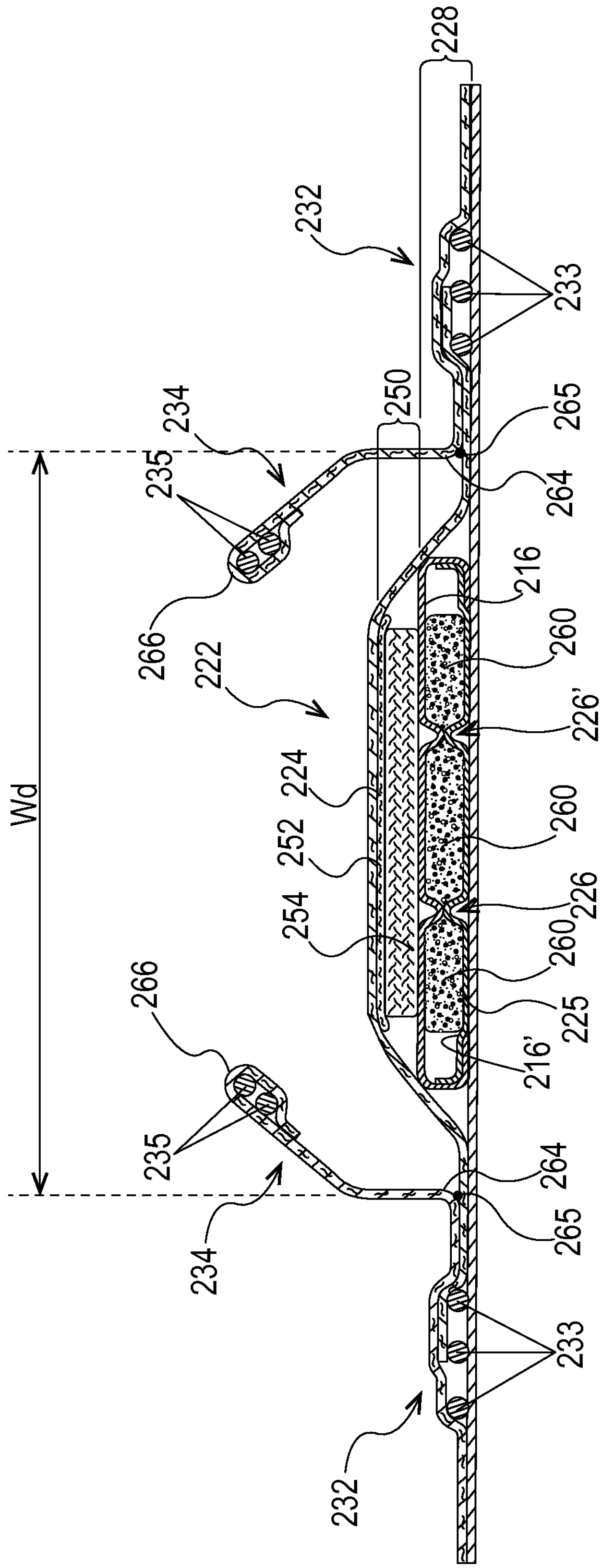
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Fig. 29

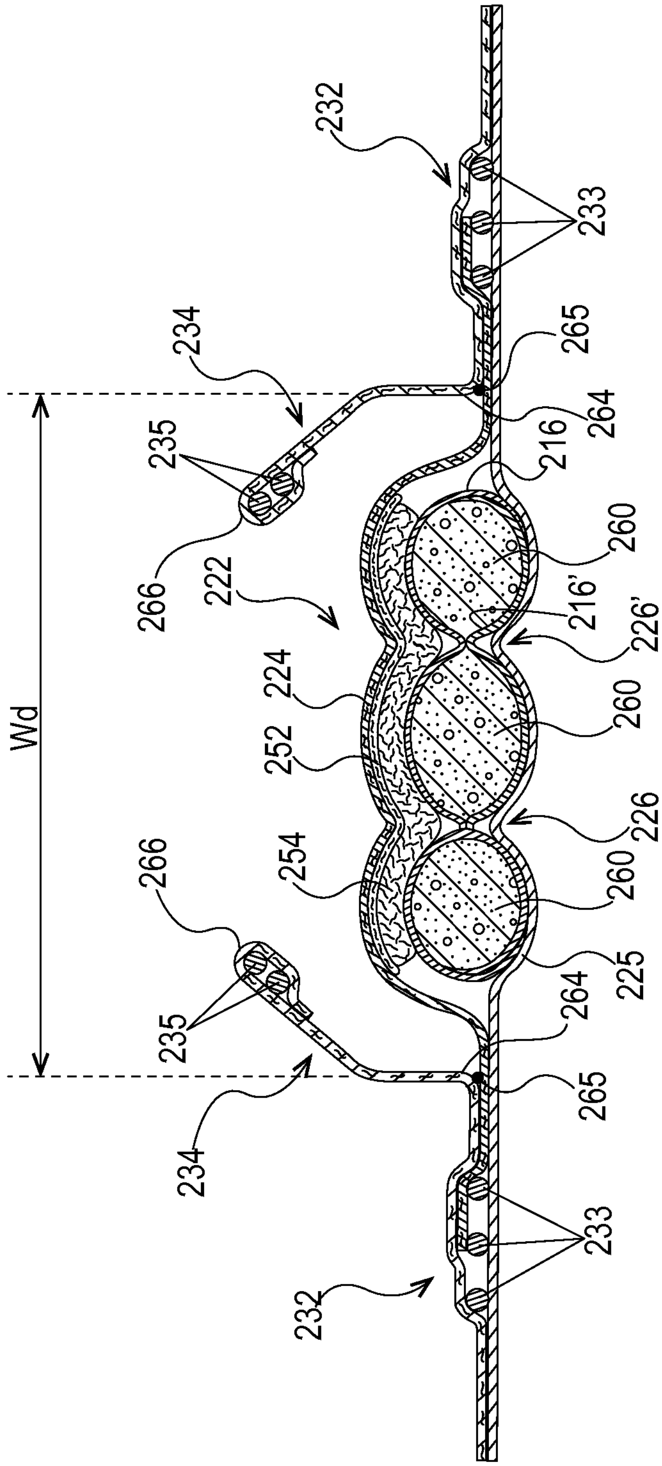
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Fig. 30

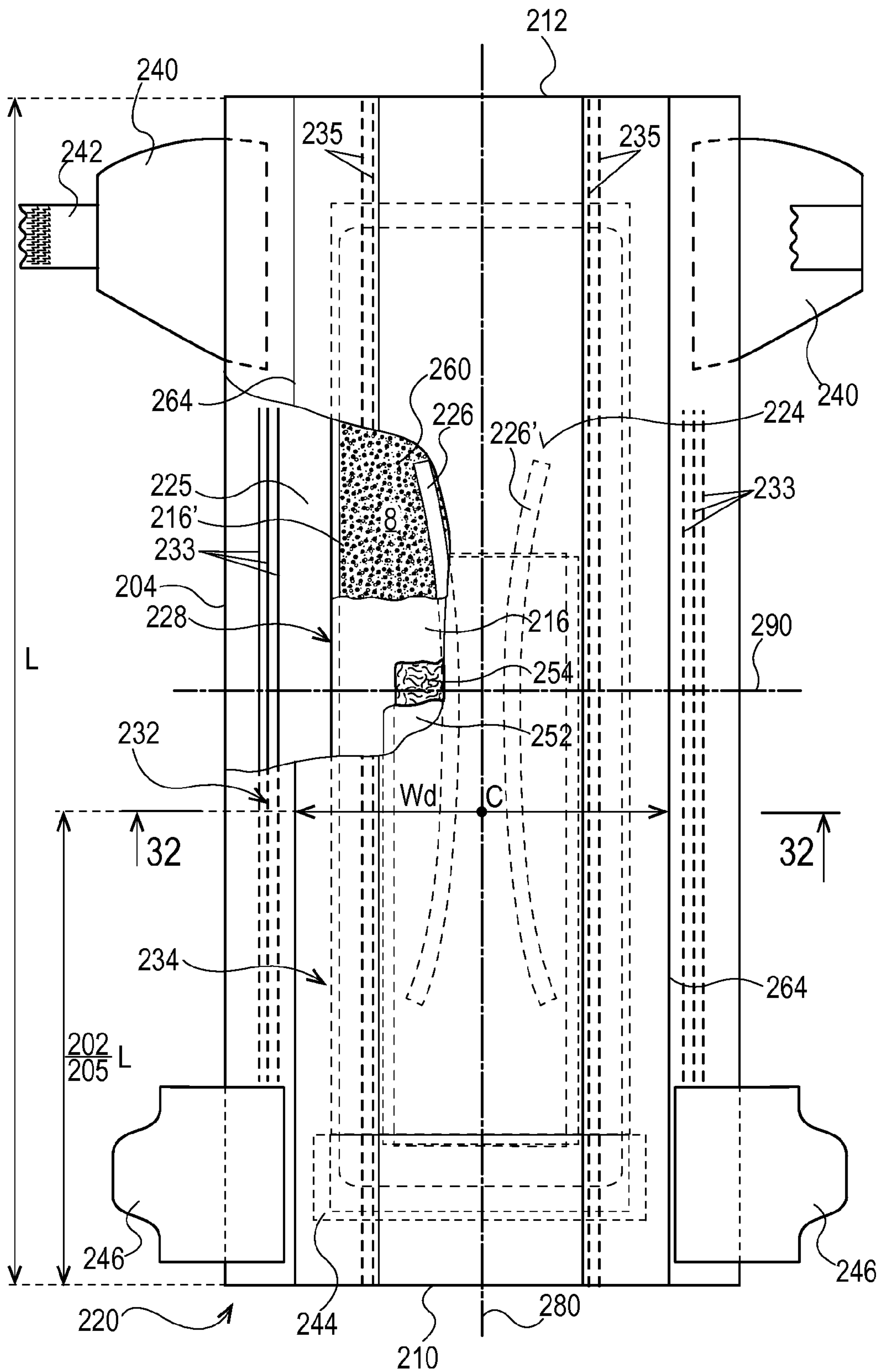
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Fig. 31

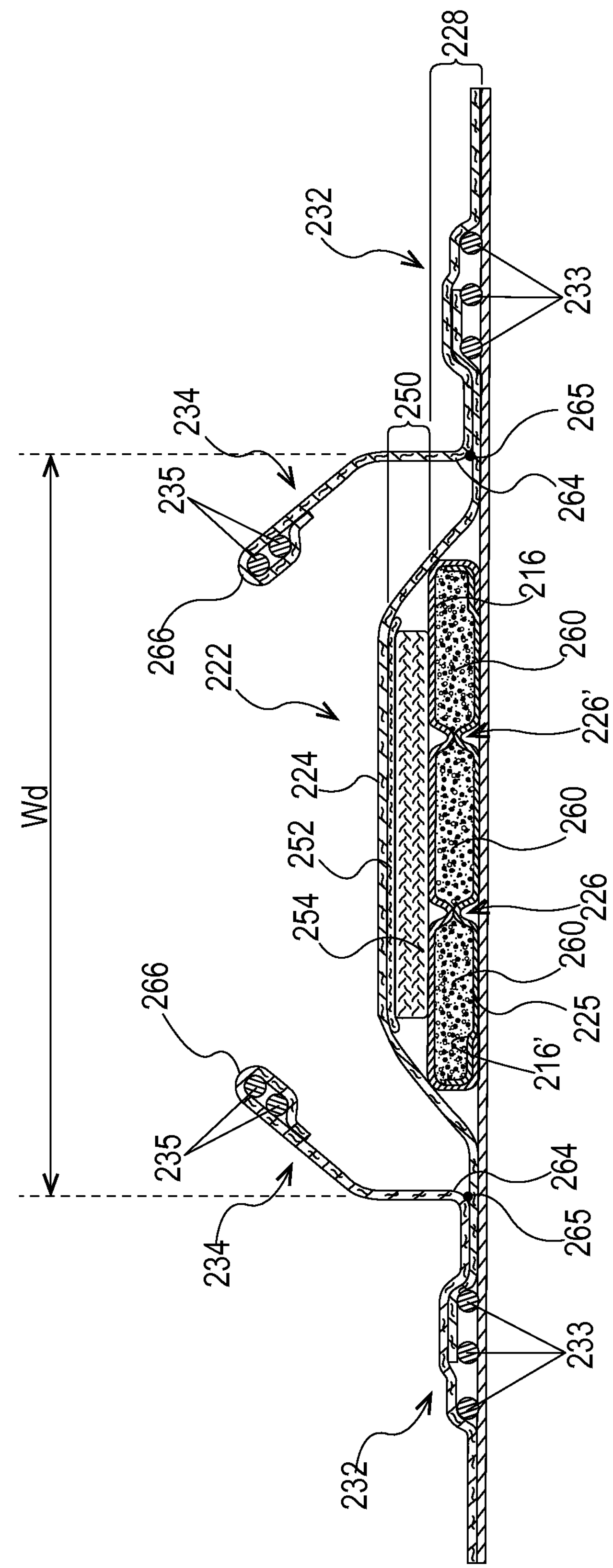
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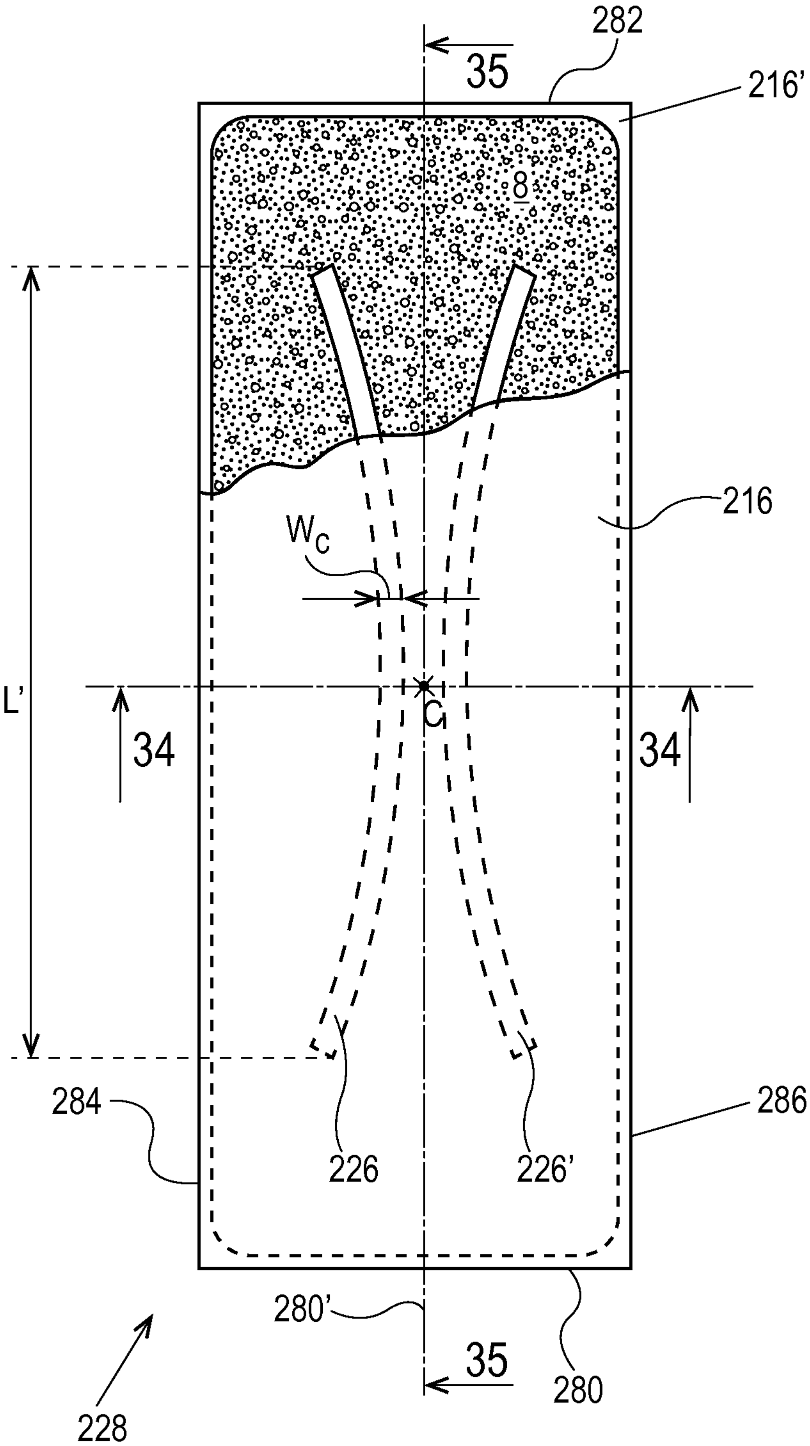
Fig. 32



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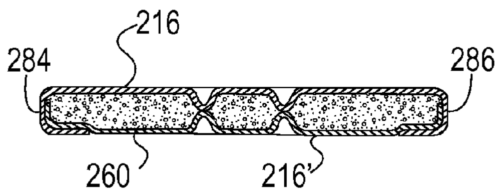
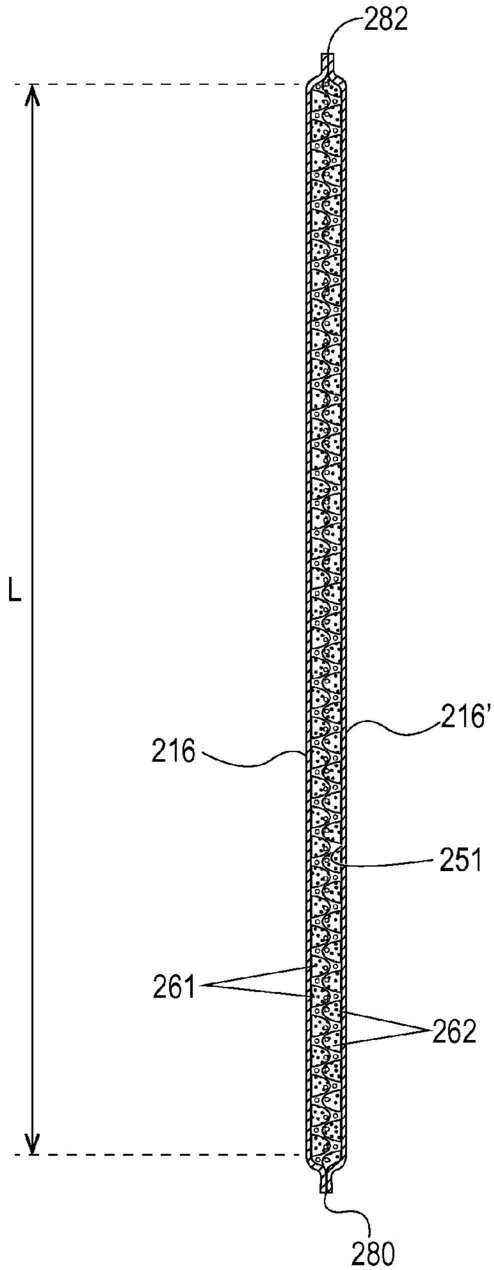


Fig. 34



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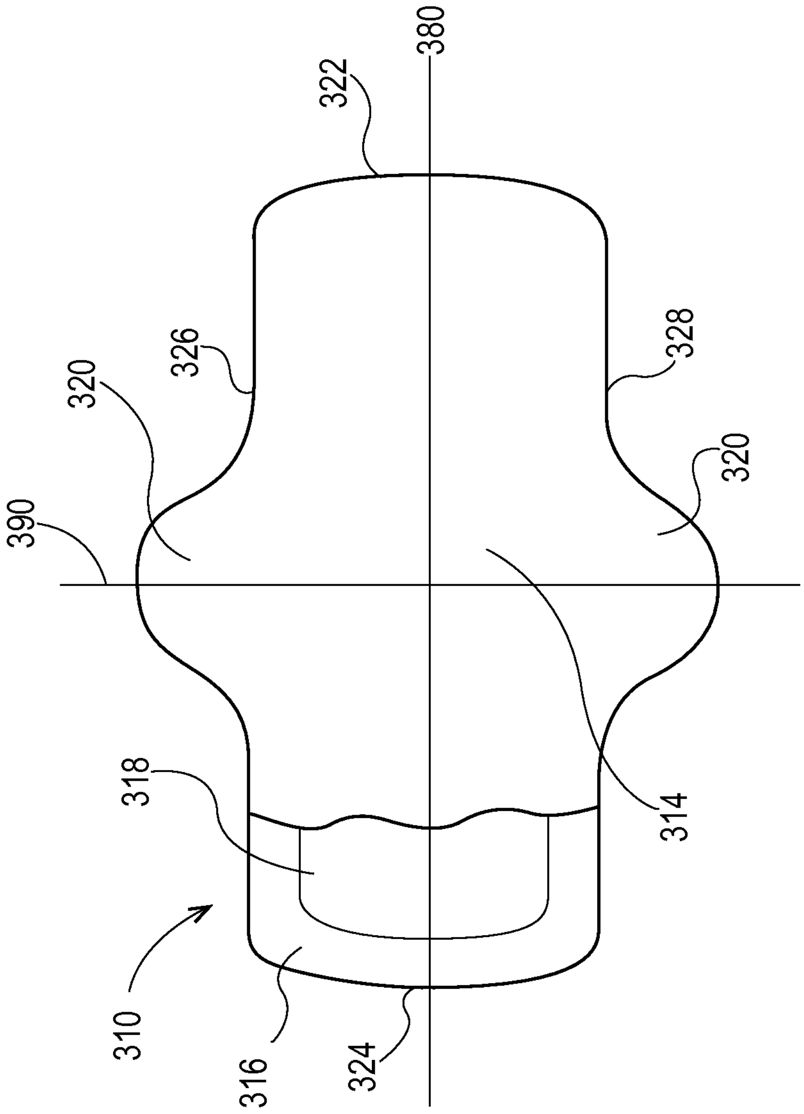

Fig. 36

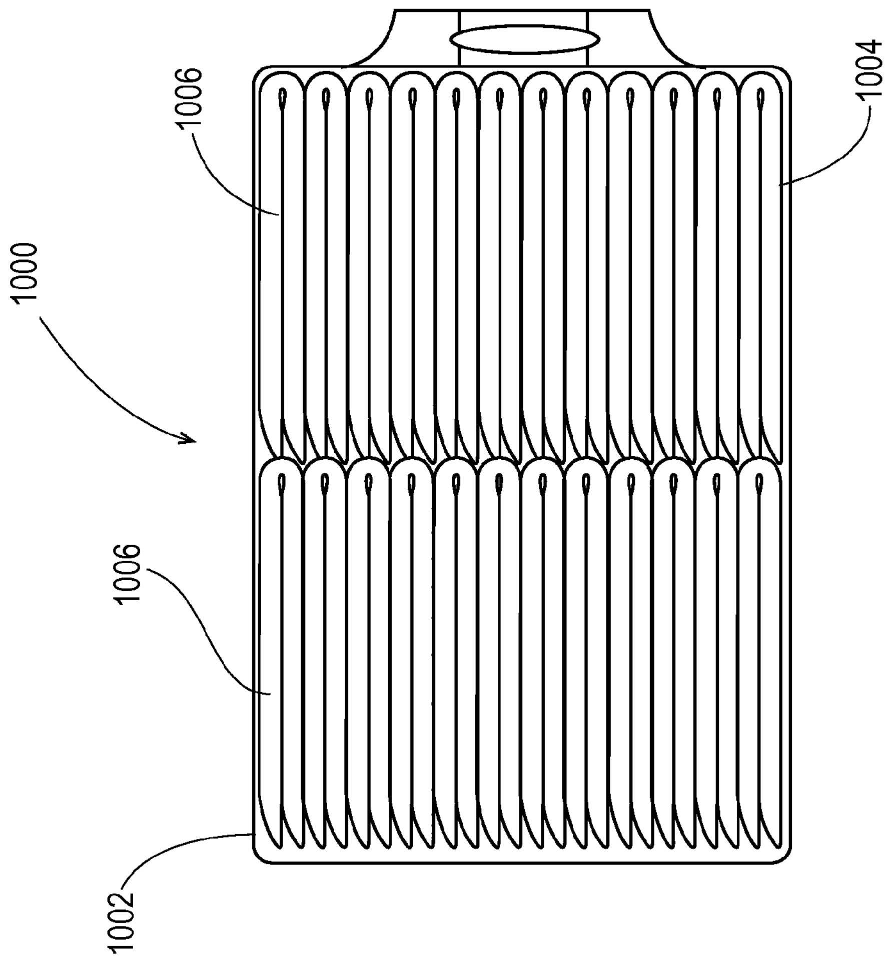

Fig. 37

ABSORBENT ARTICLES

RELATED APPLICATIONS

[0001] This application claims priority under 35 U.S.C. §119(e) to U.S. Provisional Patent Application Ser. Nos. 62/049,516 (P&G 13530P), 62/049,521 (P&G 13531PQ), 62/049,408 (P&G CM4137FPQ), 62/049,406 (P&G CM4136FPQ), 62/049,404 (P&G CM4135FPQ), 62/049,403 (P&G CM4134FPQ), 62/049,401 (P&G CM4133FPQ), 62/049,397 (P&G CM4132FPQ), and 62/049,392 (P&G CM4131FPQ), all of which were filed on Sep. 12, 2014, and to U.S. Provisional Patent Application Ser. Nos. 62/210,005 (P&G 13971PQ), 62/210,014 (P&G 13972PQ), 62/210,020 (P&G 13973PQ), and 62/210,057 (P&G CM 4131P2Q), all of which were filed on Aug. 26, 2015. The entire disclosures of all of the above-referenced U.S. Provisional Patent Applications are fully incorporated herein by reference.

FIELD

[0002] The present disclosure relates to absorbent articles, and more particularly relates to absorbent articles having substantially airfelt-free cores or airfelt-free cores in combination with three-dimensional nonwoven materials.

BACKGROUND

[0003] Absorbent articles are used to absorb and contain bodily exudates (e.g., urine, menses, BM). The absorbent articles are often configured as diapers, pants, adult incontinence articles, or sanitary napkins, for example. Conventional absorbent articles have absorbent cores comprising superabsorbent polymers and cellulosic fibers (for example, sometimes 50% or more cellulosic fibers by weight). These conventional absorbent cores provide absorbent articles with thickness and bulk characteristics typical of an absorbent comprising an assembly of defibered cellulosic fibers. The thickness and bulk of the absorbent articles provides consumer perceptions of absorbency and performance, while also providing the absorbent articles with sufficient capillary void volume to manage large single bodily exudate insults or multiple insults. These absorbent articles typically have a flat or planar topsheet.

[0004] In recent years, one or more absorbent article manufacturers have produced absorbent articles comprising absorbent cores with little or no cellulosic fibers. These cores are known as "airfelt-free" cores and typically comprise superabsorbent polymers and optionally one or more hotmelt adhesives to hold the superabsorbent polymers in position within the absorbent core. Some airfelt-free cores rely upon other mechanisms than hotmelt adhesives, for example mechanical entrapment in pockets, to hold the superabsorbent polymers in position within the absorbent core during use. Airfelt-free cores are much thinner than traditional absorbent cores in that cellulosic fibers are either not present or are present at a very low level by weight within the absorbent cores. These thin airfelt-free cores are generally combined with flat or planar topsheets and flat or planer acquisition layers in absorbent articles. As a result, the overall absorbent articles having an airfelt-free core are much thinner than conventional absorbent articles. The thinness of these absorbent articles can lead to the consumer perceptions of lack of absorbency and inadequate performance, although this is not technically accurate, since the superabsorbent polymers have sufficient absorbency and performance attributes. Another issue with the thinness of the absorbent articles comprising airfelt-free cores is the reduction in capillary void volume within the absorbent articles because of the removal of all of, or most of, the cellulosic fibers within the absorbent core. When capillary void volume in an absorbent article is reduced, the absorbent article may be challenged in handling large bodily exudates insults or multiple bodily exudates insults within a short period of time. Typically, addition of capillary void volume absorbent materials to an absorbent article increases the thickness of the articles which is a negative for consumers seeking thin, high performance absorbent articles packaged with low bulk packages. What is needed are absorbent articles comprising airfelt-free cores that overcome the above-stated problems.

SUMMARY

[0005] The present disclosure solves the problems associated with absorbent articles comprising airfelt-free cores and planar topsheets by providing absorbent articles comprising airfelt-free cores and high loft, three-dimensional nonwoven materials. The nonwoven materials may be used as topsheets or as topsheet/acquisition layer laminates. Unexpectedly, the three-dimensional nonwoven materials of the present disclosure increase the capillary void volume within the absorbent articles comprising airfelt-free cores while still preserving the ability to ship the absorbent articles with a low stack height so as to have low distribution costs for the consumer and the manufacturer. This increase in capillary void volume provides the absorbent articles comprising airfelt-free cores with better ability to receive multiple bodily exudate insults or large single insults and, thereby, makes the absorbent articles less prone to leakage. In addition, the three-dimensional nonwoven materials of the present disclosure, when used as at least part of a topsheet of an absorbent article, provide the consumer with an aesthetically pleasing absorbent article with an appearance communicating thickness and absorbency and thus consumer perception of absorbency and performance. The technical performance improvements of the absorbent articles of the present disclosure and the consumer perception improvement accompanying the absorbent articles are unexpectedly realized in combination with the ability to package the absorbent articles at stack heights where the consumer and the manufacturer also realize distribution conveniences and lower costs.

[0006] In a form, the present disclosure is directed, in part, to an absorbent article comprises a liquid permeable nonwoven material comprising a first surface and a second surface. The nonwoven material comprises a plurality of fibers and comprises a generally planar first region and a plurality of discrete integral second regions that comprise deformations forming protrusions extending outward from the first surface of the nonwoven material and openings in the second surface of the nonwoven material. The protrusions are formed from the fibers. At least some of the protrusions comprise a base proximate to the first surface of the nonwoven material, an opposed distal end extending outward in the Z-direction from the base, side walls between the base and the distal end of the protrusion, and a cap comprising at least a portion of the side walls and the distal end of the protrusion. The side walls have interior surfaces. Multiple fibers extend from the base of the protrusion to the distal end of the protrusion, and contribute to form a portion of the sides and cap of the protrusion. The fibers at least substantially surround the sides of the protrusion. The absorbent article further comprises a liquid imper-

meable material and an absorbent core positioned intermediate the liquid permeable nonwoven material and the liquid impermeable material. The absorbent core comprises an absorbent material. The absorbent material comprises at least 85% superabsorbent polymers by weight of the absorbent material.

[0007] In a form, the present disclosure is directed, in part, to an absorbent article comprises a liquid permeable nonwoven material comprising a first surface and a second surface. The nonwoven material comprises a plurality of fibers, a generally planar first region and a plurality of discrete integral second regions that comprise deformations forming protrusions extending outward from the first surface of the nonwoven material and openings in the second surface of the nonwoven material. The protrusions are formed from the fibers. At least some of the protrusions comprise a base proximate the first surface of the nonwoven material, an opposed distal end extending outward in the Z-direction from the base, side walls between the base and the distal end of the protrusion, and a cap comprising at least a portion of the side walls and the distal end of the protrusion, wherein the side walls have interior surfaces. Multiple fibers extend from the base of the protrusion to the distal end of the protrusion, and contribute to form a portion of the sides and cap of a protrusion. The interior surfaces of the side walls define a base opening at the base of the protrusion. The cap has a portion with a maximum interior width. The base opening has a width. The maximum interior width of the cap of the protrusion is greater than the width of the base opening. The absorbent article further comprising a liquid impermeable material and an absorbent core positioned intermediate the nonwoven material and the liquid impermeable material. The absorbent core comprises an absorbent material. The absorbent material comprises at least 85% superabsorbent polymers by weight of the absorbent material and a channel.

[0008] In a form, the present disclosure is directed, in part, to a package comprises a plurality of absorbent articles. At least some of the absorbent articles comprise a liquid permeable nonwoven material comprising a first surface and a second surface. The nonwoven material comprises a plurality of fibers. The nonwoven material comprises a generally planar first region and a plurality of discrete integral second regions that comprise deformations forming protrusions extending outward from the first surface of the nonwoven material and openings in the second surface of the nonwoven material. The protrusions are formed from the fibers. At least some of the protrusions comprise a base proximate the first surface of the nonwoven material, an opposed distal end extending outward in the Z-direction from the base, side walls between the base and the distal end of the protrusion, and a cap comprising at least a portion of the side walls and the distal end of the protrusion. The side walls have interior surfaces. Multiple fibers extend from the base of the protrusion to the distal end of the protrusion, and contribute to form a portion of the sides and cap of a protrusion. The interior surfaces of the side walls define a base opening at the base of the protrusion. The cap has a portion with a maximum interior width. The base opening has a width. The maximum interior width of the cap of the protrusion is greater than the width of the base opening. The at least some absorbent articles further comprise a liquid impermeable material and an absorbent core positioned intermediate the liquid permeable nonwoven material and the liquid impermeable material. The absorbent core comprises an absorbent material. The absorbent material comprises at least 85% superabsorbent polymers by weight of the absorbent material. The package has an in-bag stack height of less than about 80 mm, according to the In-Back Stack Height Test herein.

[0009] In a form, the present disclosure is directed, in part, to an absorbent article comprises a liquid pervious nonwoven material having a first surface and a second surface. The nonwoven material comprises a plurality of fibers. The nonwoven material comprises a generally planar first region and a plurality of discrete integral second regions that comprise deformations forming protrusions extending outward from the first surface of the nonwoven material and openings in the second surface of the nonwoven material. The protrusions are formed from the fibers. At least some of the protrusions have an exterior width, and two ends that define a length of the protrusion therebetween. The at least some of the protrusions comprise a base proximate the first surface of the nonwoven material, an opposed distal end extending outward in the Z-direction from the base, side walls between the base and the distal end of the protrusion, and a cap comprising at least a portion of the side walls and the distal end of the protrusion. The side walls have interior surfaces. The exterior width of the protrusion varies along the length of the protrusion when the nonwoven material is viewed from the z-direction. The absorbent article further comprises a liquid impermeable material and an absorbent core positioned intermediate the nonwoven material and the liquid impermeable material. The absorbent core comprises an absorbent material. The absorbent material comprises at least 90% superabsorbent polymers by weight of the absorbent material and a hotmelt adhesive.

[0010] In a form, the present disclosure is directed, in part, to an absorbent article comprises a liquid pervious nonwoven material having a first surface and a second surface. The nonwoven material comprises a plurality of fibers. The nonwoven material comprises a generally planar first region and a plurality of discrete integral second regions that comprise deformations forming protrusions extending outward from the first surface of the nonwoven material and openings in the second surface of the nonwoven material. The protrusions are formed from the fibers. At least some of the protrusions have an exterior width, and two ends that define a length of the protrusion therebetween, and the at least some protrusions comprise a base proximate the first surface of the nonwoven material, an opposed distal end extending outward in the Z-direction from the base, side walls between the base and the distal end of the protrusion, and a cap comprising at least a portion of the side walls and the distal end of the protrusion. The side walls have interior surfaces. The interior surfaces of the side walls define a base opening at the base of the protrusion. The cap has a portion with a maximum interior width. The base opening has a width. The maximum interior width of the cap of the protrusion is greater than the width of the base opening. The absorbent article comprises a liquid impermeable material and an absorbent core positioned intermediate the nonwoven material and the liquid impermeable material. The absorbent core comprises an absorbent material. The absorbent material comprises at least 85% superabsorbent polymers by weight of the absorbent material and a hotmelt adhesive.

[0011] In a form, the present disclosure is directed, in part, to a package comprises a plurality of absorbent articles. At least some of the absorbent articles comprise a liquid pervious nonwoven material having a first surface and a second surface. The nonwoven material comprises a plurality of fibers. The nonwoven material comprises a generally planar first region and a plurality of discrete integral second regions that comprise deformations forming protrusions extending outward from the first surface of the nonwoven material and openings in the second surface of the nonwoven material. The protrusions are formed from the fibers. At least some of the protrusions have an exterior width, and two ends that define a length of the protrusion therebetween. The at least some protrusions comprise a base proximate the first surface of the nonwoven material, an opposed distal end extending outward in the Z-direction from the base, side walls between the base and the distal end of the protrusion, and a cap comprising at least a portion of the side walls and the distal end of the protrusion. The side walls have interior surfaces. The interior surfaces of the side walls define a base opening at the base of the protrusion. The cap has a portion with a maximum interior width. The base opening has a width. The maximum interior width of the cap of the protrusion is greater than the width of the base opening. The at least some absorbent articles further comprising a liquid impermeable material and an absorbent core positioned intermediate the liquid permeable nonwoven material and the liquid impermeable material. The absorbent core comprises an absorbent material. The absorbent material comprises at least 85% superabsorbent polymers by weight of the absorbent material and a hotmelt adhesive. The package has an in-bag stack height of less than about 80 mm, according to the In-Back Stack Height Test herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The above-mentioned and other features and advantages of the present disclosure, and the manner of attaining them, will become more apparent and the disclosure itself will be better understood by reference to the following description of non-limiting embodiments of the disclosure taken in conjunction with the accompanying drawings, wherein:

[0013] FIG. **1** is a photomicrograph showing the end view of a prior art tuff;

[0014] FIG. **2** is a schematic end view of a prior art tuft after it has been subjected to compression;

[0015] FIG. **3** is a photomicrograph of the end of a prior art nonwoven web showing a plurality of collapsed tufts;

[0016] FIG. **4** is a schematic side view of a prior art conical-shaped structure before and after it has been subjected to compression;

[0017] FIG. **5** is a plan view photomicrograph showing one side of a nonwoven material having three-dimensional deformations formed therein, with the protrusions oriented upward in accordance with the present disclosure;

[0018] FIG. **6** is a plan view photomicrograph showing the other side of a nonwoven material similar to that shown in FIG. **5**, with the openings in the nonwoven facing upward in accordance with the present disclosure;

[0019] FIG. **7** is a Micro CT scan image showing a perspective view of a protrusion in a single layer nonwoven material in accordance with the present disclosure;

[0020] FIG. **8** is a Micro CT scan image showing a side of a protrusion in a single layer nonwoven material in accordance with the present disclosure;

[0021] FIG. **9** is a Micro CT scan image showing a perspective view of a deformation with the opening facing upward in a single layer nonwoven material in accordance with the present disclosure;

[0022] FIG. **10** is a perspective view of a deformation in a two layer nonwoven material with the opening facing upward in accordance with the present disclosure;

[0023] FIG. **11** is a photomicrograph of a cross-section taken along the transverse axis of a deformation showing one example of a multi-layer nonwoven material having a three-dimensional deformation in the form of a protrusion on one side of the material that provides a wide opening on the other side of the material, with the opening facing upward in accordance with the present disclosure;

[0024] FIG. **12** is a schematic view of the protrusion shown in FIG. **11** in accordance with the present disclosure;

[0025] FIG. **13** is a plan view photomicrograph from the protrusion side of a material after it has been subjected to compression showing the high fiber concentration region around the perimeter of the protrusion in accordance with the present disclosure;

[0026] FIG. **14** is a photomicrograph of the cross-section of a protrusion taken along the transverse axis of the protrusion showing the protrusion after it has been subjected to compression in accordance with the present disclosure;

[0027] FIG. **15**A is a cross-sectional view taken along the transverse axis of a deformation of one embodiment of a multi-layer nonwoven web shown with the base opening facing upward in accordance with the present disclosure;

[0028] FIG. **15**B is a cross-sectional view taken along the transverse axis of a deformation of an alternative embodiment of a multi-layer nonwoven web shown with the base opening facing upward in accordance with the present disclosure;

[0029] FIG. **15**C is a cross-sectional view taken along the transverse axis of a deformation of an alternative embodiment of a multi-layer nonwoven web shown with the base opening facing upward in accordance with the present disclosure;

[0030] FIG. **15**D is a cross-sectional view taken along the transverse axis of a deformation of an alternative embodiment of a multi-layer nonwoven web shown with the base opening facing upward in accordance with the present disclosure;

[0031] FIG. **15**E is a cross-sectional view taken along the transverse axis of a deformation of an alternative embodiment of a multi-layer nonwoven web shown with the base opening facing upward in accordance with the present disclosure;

[0032] FIG. **15**F is a cross-sectional view taken along the transverse axis of a deformation of an alternative embodiment of a multi-layer nonwoven web shown with the base opening facing upward in accordance with the present disclosure;

[0033] FIG. **16** is a plan view photomicrograph of a nonwoven web with the protrusions oriented upward showing the concentration of fibers in one layer in of a two layer structure in accordance with the present disclosure;

[0034] FIG. **17** is a perspective view photomicrograph showing the reduced fiber concentration in the side walls of the protrusions in a layer similar to that shown in FIG. **16** in accordance with the present disclosure;

[0035] FIG. **18** is a plan view photomicrograph of a nonwoven web with the protrusions oriented upward showing the reduced concentration of fibers in the cap of a protrusion in the other layer of a two layer structure in accordance with the present disclosure;

[0036] FIG. **19** is a perspective view photomicrograph showing the increased fiber concentration in the side walls of the protrusions in a layer similar to that shown in FIG. **18** in accordance with the present disclosure;

[0037] FIG. **20** is a perspective view photomicrograph of one layer of a multiple layer nonwoven material on the surface of a forming roll showing the "hanging chads" that can be formed in one of the layers when some nonwoven precursor web materials are used in accordance with the present disclosure;

[0038] FIG. **21** is a perspective view of one example of an apparatus for forming the nonwoven materials described herein in accordance with the present disclosure;

[0039] FIG. **22** is an enlarged perspective view of a portion of the male roll shown in FIG. **21** in accordance with the present disclosure;

[0040] FIG. **23** is an enlarged perspective view showing the nip between the rolls shown in FIG. **21** in accordance with the present disclosure;

[0041] FIG. **24** is a schematic perspective view of one version of a method of making nonwoven materials having deformations therein where two precursor materials are used, one of which is a continuous web and the other of which is in the form of discrete pieces in accordance with the present disclosure;

[0042] FIG. **25** is an absorbent article in the form of a diaper comprising an exemplary topsheet/acquisition layer composite structure wherein the length of the acquisition layer is less that the length of the topsheet with some layers partially removed in accordance with the present disclosure;

[0043] FIG. **26** is one transverse cross-section of the diaper of FIG. **25** taken along line **26-26** in accordance with the present disclosure;

[0044] FIG. **27** is an alternative transverse cross-section of the diaper of FIG. **25** in accordance with the present disclosure;

[0045] FIG. **28** is a top view of an example absorbent article, wearer-facing surface facing the viewer, with some layers partially removed in accordance with the present disclosure;

[0046] FIG. **29** is a cross-sectional view of the absorbent article taken about line **29-29** of FIG. **28** in accordance with the present disclosure;

[0047] FIG. **30** is a cross-sectional view of the absorbent article taken about line **29-29** of FIG. **28** where the absorbent article has been loaded with fluid in accordance with the present disclosure;

[0048] FIG. **31** is a top view of another absorbent article, wearer-facing surface facing the viewer, with some layers partially removed in accordance with the present disclosure;

[0049] FIG. **32** is a cross-sectional view of the absorbent article taken about line **32-32** of FIG. **31** in accordance with the present disclosure;

[0050] FIG. **33** is a top view of an example absorbent core of the absorbent article of FIG. **31** with some layers partially removed in accordance the present disclosure;

[0051] FIG. **34** is a cross-sectional view of the absorbent core taken about line **34-34** of FIG. **33** in accordance with the present disclosure;

[0052] FIG. **35** is a cross-sectional view of the absorbent core taken about line **35-35** of FIG. **33** in accordance with the present disclosure;

[0053] FIG. **36** is a top view of another example absorbent article, wearer-facing surface facing the viewer, that is a sanitary napkin with some of the layers cut away in accordance with the present disclosure; and

[0054] FIG. **37** is a side view of a package of absorbent articles showing the package width in accordance with the present disclosure. The outer surface is illustrated as transparent for purposes of clarity.

DETAILED DESCRIPTION

[0055] Various non-limiting embodiments of the present disclosure will now be described to provide an overall understanding of the principles of the structure, function, manufacture, and use of the absorbent articles disclosed herein. One or more examples of these non-limiting embodiments are illustrated in the accompanying drawings. Those of ordinary skill in the art will understand that the absorbent articles described herein and illustrated in the accompanying drawings are non-limiting example embodiments and that the scope of the various non-limiting embodiments of the present disclosure are defined solely by the claims. The features illustrated or described in connection with one non-limiting embodiment may be combined with the features of other non-limiting embodiments. Such modifications and variations are intended to be included within the scope of the present disclosure.

DEFINITIONS

[0056] The term "absorbent article" includes disposable articles such as sanitary napkins, panty liners, tampons, interlabial devices, wound dressings, diapers, adult incontinence articles, wipes, and the like. At least some of such absorbent articles are intended for the absorption of body liquids, such as menses or blood, vaginal discharges, urine, and feces. Wipes may be used to absorb body liquids, or may be used for other purposes, such as for cleaning surfaces. Various absorbent articles described above will typically comprise a liquid pervious topsheet, a liquid impervious backsheet joined to the topsheet, and an absorbent core between the topsheet and backsheet. The nonwoven material described herein can comprise at least part of other articles such as scouring pads, wet or dry-mop pads (such as SWIFFER® pads), and the like.

[0057] The term "absorbent core", as used herein, refers to the component of the absorbent article that is primarily responsible for storing liquids. As such, the absorbent core typically does not include the topsheet or backsheet of the absorbent article.

[0058] The term "aperture", as used herein, refers to a regular or substantially regularly-shaped hole that is intentionally formed and extends completely through a web or structure (that is, a through hole). The apertures can either be punched cleanly through the web so that the material surrounding the aperture lies in the same plane as the web prior to the formation of the aperture (a "two dimensional" aperture), or the holes can be formed such that at least some of the material surrounding the opening is pushed out of the plane of the web. In the latter case, the apertures may resemble a depression with an aperture therein, and may be referred to herein as a "three dimensional" aperture, a subset of apertures.

[0059] The term "component" of an absorbent article, as used herein, refers to an individual constituent of an absorbent article, such as a topsheet, acquisition layer, liquid handling layer, absorbent core or layers of absorbent cores, backsheets, and barriers such as barrier layers and barrier cuffs.

[0060] The term "cross-machine direction" or "CD" means the path that is perpendicular to the machine direction in the plane of the web.

[0061] The term "deformable material", as used herein, is a material which is capable of changing its shape or density in response to applied stresses or strains.

[0062] The term "discrete", as used herein, means distinct or unconnected. When the term "discrete" is used relative to forming elements on a forming member, it is meant that the distal (or radially outwardmost) ends of the forming elements are distinct or unconnected in all directions, including in the machine and cross-machine directions (even though bases of the forming elements may be formed into the same surface of a roll, for example).

[0063] The term "disposable" is used herein to describe absorbent articles and other products which are not intended to be laundered or otherwise restored or reused as an absorbent article or product (i.e., they are intended to be discarded after use and, preferably, to be recycled, composted or otherwise disposed of in an environmentally compatible manner).

[0064] The term "forming elements", as used herein, refers to any elements on the surface of a forming member that are capable of deforming a web.

[0065] The term "integral", as used herein as in "integral extension" when used to describe the protrusions, refers to fibers of the protrusions having originated from the fibers of the precursor web(s). Thus, as used herein, "integral" is to be distinguished from fibers introduced to or added to a separate precursor web for the purpose of making the protrusions.

[0066] The term "joined to" encompasses configurations in which an element is directly secured to another element by affixing the element directly to the other element; configurations in which the element is indirectly secured to the other element by affixing the element to intermediate member(s) which in turn are affixed to the other element; and configurations in which one element is integral with another element, i.e., one element is essentially part of the other element. The term "joined to" encompasses configurations in which an element is secured to another element at selected locations, as well as configurations in which an element is completely secured to another element across the entire surface of one of the elements. The term "joined to" includes any known manner in which elements can be secured including, but not limited to mechanical entanglement.

[0067] The term "machine direction" or "MD" means the path that material, such as a web, follows through a manufacturing process.

[0068] The term "macroscopic", as used herein, refers to structural features or elements that are readily visible and distinctly discernable to a human having 20/20 vision when the perpendicular distance between the viewer's eye and the web is about 12 inches (30 cm). Conversely, the term "microscopic" refers to such features that are not readily visible and distinctly discernable under such conditions.

[0069] The term "mechanically deforming", as used herein, refers to processes in which a mechanical force is exerted upon a material in order to permanently deform the material.

[0070] The term "permanently deformed", as used herein, refers to the state of a deformable material whose shape or density has been permanently altered in response to applied stresses or strains.

[0071] The terms "SELF" and "SELF'ing", refer to Procter & Gamble technology in which SELF stands for Structural Elastic Like Film. While the process was originally developed for deforming polymer film to have beneficial structural characteristics, it has been found that the SELF'ing process can be used to produce beneficial structures in other materials. Processes, apparatuses, and patterns produced via SELF are illustrated and described in U.S. Pat. Nos. 5,518,801; 5,691,035; 5,723,087; 5,891,544; 5,916,663; 6,027,483; and 7,527,615 B2.

[0072] The term "tuft", as used herein, refers to a particular type of feature that may be formed from fibers in a nonwoven web. Tufts may have a tunnel-like configuration which may be open at both of their ends.

[0073] The term "web" is used herein to refer to a material whose primary dimension is X-Y, i.e., along its length (or longitudinal direction) and width (or transverse direction). It should be understood that the term "web" is not necessarily limited to single layers or sheets of material. Thus the web can comprise laminates or combinations of several sheets of the requisite type of materials.

[0074] The term "Z-dimension" refers to the dimension orthogonal to the length and width of the web or article. The Z-dimension usually corresponds to the thickness of the web or material. As used herein, the term "X-Y dimension" refers to the plane orthogonal to the thickness of the web or material. The X-Y dimension usually corresponds to the length and width, respectively, of the web or material.

Nonwoven Materials

[0075] The present disclosure is directed, in part, to high-loft nonwoven materials having discrete three-dimensional deformations, which deformations provide protrusions on one side of the material, and openings on the other side of the nonwoven materials. Methods of making the nonwoven materials are also disclosed. The nonwoven materials can be used in absorbent articles and other articles, as will be described in further detail below.

[0076] As used herein, the term "nonwoven" refers to a web or material having a structure of individual fibers or threads which are interlaid, but not in a repeating pattern as in a woven or knitted fabric, which latter types of fabrics do not typically have randomly oriented or substantially randomly-oriented fibers. Nonwoven webs will have a machine direction (MD) and a cross machine direction (CD) as is commonly known in the art of web manufacture. By "substantially randomly oriented" is meant that, due to processing conditions of the precursor web, there may be a higher amount of fibers oriented in the MD than the CD, or vice versa. For example, in spunbonding and meltblowing processes continuous strands of fibers are deposited on a support moving in the MD. Despite attempts to make the orientation of the fibers of the spunbond or meltblown nonwoven web truly "random," usually a slightly higher percentage of fibers are oriented in the MD as opposed to the CD.

[0077] Nonwoven webs and materials are often incorporated into products, such as absorbent articles, at high manufacturing line speeds. Such manufacturing processes can apply compressive and shear forces on the nonwoven webs that may damage certain types of three-dimensional features that have been purposefully formed in such webs. In addition, in the event that the nonwoven material is incorporated into a product (such as a disposable diaper) that is made or packaged under compression, it becomes difficult to preserve the three-dimensional character of some types of prior three-dimensional features after the material is subjected to such compressive forces.

[0078] For instance, FIGS. **1** and **2** show an example of a prior art nonwoven material **10** with a tufted structure. The nonwoven material comprises tufts **12** formed from looped fibers **14** that form a tunnel-like structure having two ends **16**. The tufts **12** extend outward from the plane of the nonwoven material in the Z-direction. The tunnel-like structure has a width that is substantially the same from one end of the tuft to the opposing end. Often, such tufted structures will have holes or openings **18** at both ends and an opening **20** at their base. Typically, the openings **18** at the ends of the tufts are at the machine direction (MD) ends of the tufts. The openings **18** at the ends of the tufts can be a result of the process used to form the tufts. If the tufts **12** are formed by forming elements in the form of teeth with a relatively small tip and vertical leading and trailing edges that form a sharp point, these leading and/or trailing edges may punch through the nonwoven web at least one of the ends of the tufts. As a result, openings **18** may be formed at one or both ends of the tufts **12**.

[0079] While such a nonwoven material **10** provides well-defined tufts **12**, the opening **20** at the base of the tuft structure can be relatively narrow and difficult to see with the naked eye. In addition, as shown in FIG. **2**, the material of the tuft **12** surrounding this narrow base opening **20** may tend to form a hinge **22**, or pivot point if forces are exerted on the tuft. If the nonwoven is compressed (such as in the Z-direction), in many cases, the tufts **12** can collapse to one side and close off the opening **20**. Typically, a majority of the tufts in such a tufted material will collapse and close off the openings **20**. FIG. **2** schematically shows an example of a tuft **12** after it has collapsed. In FIG. **2**, the tuft **12** has folded over to the left side. FIG. **3** is an image showing a nonwoven material with several upwardly-oriented tufts, all of which have folded over to the side. However, not all of the tufts **12** will collapse and fold over to the same side. Often, some tufts **12** will fold to one side, and some tufts will fold to the other side. As a result of the collapse of the tufts **12**, the openings **20** at the base of the tufts can close up, become slit-like, and virtually disappear.

[0080] Prior art nonwoven materials with certain other types of three dimensional deformations, such as conical structures, can also be subject to collapse when compressed. As shown in FIG. **4**, conical structures **24** will not necessarily fold over as will certain tufted structures when subjected to compressive forces F. However, conical structures **24** can be subject to collapse in that their relatively wide base opening **26** and smaller tip **28** causes the conical structure to push back toward the plane of the nonwoven material, such as to the configuration designated **24**A.

[0081] The nonwoven materials of at least some embodiments of the present disclosure described herein are intended to better preserve the structure of discrete three-dimensional features in the nonwoven materials after compression.

[0082] FIGS. **5-14** show examples of nonwoven materials **30** with three-dimensional deformations comprising protrusions **32** therein. The nonwoven materials **30** have a first surface **34**, a second surface **36**, and a thickness T therebetween (the thickness being shown in FIG. **12**). FIG. **5** shows the first surface **34** of a nonwoven material **30** with the protrusions **32** that extend outward from the first surface **34** of the nonwoven material oriented upward. FIG. **6** shows the second surface **36** of a nonwoven material **30** such as that shown in FIG. **5**, having three-dimensional deformations formed therein, with the protrusions oriented downward and the base openings **44** oriented upward. FIG. **7** is a Micro CT scan image showing a perspective view of a protrusion **32**. FIG. **8** is a Micro CT scan image showing a side view of a protrusion **32** (of one of the longer sides of the protrusion). FIG. **9** is a Micro CT scan image showing a perspective view of a deformation with the opening **44** facing upward. The nonwoven materials **30** comprise a plurality of fibers **38** (shown in FIGS. **7-11** and **14**). As shown in FIGS. **7** and **9**, the nonwoven material **30** may have a plurality of bonds **46** therein to hold the fibers **38** together. Any such bonds are typically present in the precursor material.

[0083] The protrusions **32** may, in some cases, be formed from looped fibers (which may be continuous) **38** that are pushed outward so that they extend out of the plane of the nonwoven web in the Z-direction. The protrusions **32** will typically comprise more than one looped fiber. In some cases, the protrusions **32** may be formed from looped fibers and at least some broken fibers. In addition, in the case of some types of nonwoven materials (such as carded materials, which are comprised of shorter fibers), the protrusions **32** may be formed from loops comprising multiple discontinuous fibers. Multiple discontinuous fibers in the form of a loop are shown as layer **30**A in FIGS. **15**A-**15**F. The looped fibers may either be aligned (that is, oriented in substantially the same direction), or not be aligned within the protrusions **32**. Typically, if male/female forming elements are used to form the protrusions, and the female forming elements substantially surround the male forming elements, the fibers in the protrusions **32** may remain substantially randomly oriented (rather than aligned), similar to their orientation in the precursor web(s) from which the nonwoven materials **30** are formed.

[0084] The nonwoven material **30** may comprise a generally planar first region **40** and the three-dimensional deformations may comprise a plurality of discrete integral second regions **42**. The term "generally planar" is not meant to imply any particular flatness, smoothness, or dimensionality. Thus, the first region **40** can include other features that provide the first region **40** with a topography. Such other features can include, but are not limited to small projections, raised network regions around the base openings **44**, and other types of features. Thus, the first region **40** is generally planar when considered relative to the second regions **42**.

[0085] The term "deformation", as used herein, includes both the protrusions **32** formed on one side of the nonwoven material and the base openings **44** formed in the opposing side of the material. The base openings **44** are most often not in the form of an aperture or a through-hole. The base openings **44** may instead appear as depressions. The base openings **44** can be analogized to the opening of a bag. A bag has an opening that typically does not pass completely through the bag. In the case of the present nonwoven materials **30**, as shown in FIG. **10**, the base openings **44** open into the interior of the protrusions **32**.

[0086] FIG. **11** shows one example of a multi-layer nonwoven material **30** having a three-dimensional deformation in the form of a protrusion **32** on one side of the material that provides a wide base opening **44** on the other side of the material. The dimensions of "wide" base openings are described in further detail below. In this case, the base opening **44** is oriented upward in the figure. When there is more than one nonwoven layer, the individual layers can be designated **30**A, **30**B, etc. The individual layers **30**A and **30**B each have first and second surfaces, which can be designated similarly to the first and second surfaces **34** and **36** of the nonwoven material (e.g., **34**A and **36**A for the first and second surfaces of the first layer **30**A; and, **34**B and **36**B for the first and second surfaces of the second layer **30**B).

[0087] As shown in FIGS. **11** and **12**, the protrusions **32** comprise: a base **50** proximate the first surface **34** of the nonwoven material; an opposed enlarged distal portion or cap portion, or "cap" **52**, that extends to a distal end **54**; side walls (or "sides") **56**; an interior **58**; and a pair of ends **60** (the latter being shown in FIG. **5**). The "base" **50** of the protrusions **32** comprises the narrowest portion of the protrusion when viewed from one of the ends of the protrusion. The term "cap" does not imply any particular shape, other than it comprises the wider portion of the protrusion **32** that includes and is adjacent to the distal end **54** of the protrusion **32**. The side walls **56** have an inside surface **56**A and an outside surface **56**B. As shown in FIGS. **11** and **12**, the side walls **56** transition into, and may comprise part of the cap **52**. Therefore, it is not necessary to precisely define where the side walls **56** end and the cap **52** begins. The cap **52** will have a maximum interior width, W_I, between the inside surfaces **56**A of the opposing side walls **56**. The cap **52** will also have a maximum exterior width W between the outside surfaces **56**B of the opposing side walls **56**. The ends **60** of the protrusions **32** are the portions of the protrusions that are spaced furthest apart along the longitudinal axis, L, of the protrusions.

[0088] As shown in FIGS. **11** and **12**, the narrowest portion of the protrusion **32** defines the base opening **44**. The base opening **44** has a width W_O. The base opening **44** may be located (in the z-direction) between the plane defined by the second surface **36** of the material and the distal end **54** of the protrusion. As shown in FIGS. **11** and **12**, the nonwoven material **30** may have an opening in the second surface **36** (the "second surface opening" **64**) that transitions into the base opening **44** (and vice versa), and is the same size as, or larger than the base opening **44**. The base opening **44** will, however, generally be discussed more frequently herein since its size will often be more visually apparent to the consumer in those embodiments where the nonwoven material **30** is placed in an article with the base openings **44** visible to the consumer. It should be understood that in certain embodiments, such as in embodiments in which the base openings **44** face outward (for example, toward a consumer and away from the absorbent core in an absorbent article), it may be desirable for the base openings **44** not to be covered and/or closed off by another web.

[0089] As shown in FIG. **12**, the protrusions **32** have a depth D measured from the second surface **36** of the nonwoven web to the interior of the protrusion at the distal end **54** of the protrusions. The protrusions **32** have a height H measured from the second surface **36** of the nonwoven web to the distal end **54** of the protrusions. In most cases the height H of the protrusions **32** will be greater than the thickness T of the first region **40**. The relationship between the various portions of the deformations may be such that as shown in FIG. **11**, when viewed from the end, the maximum interior width W_I of the cap **52** of the protrusions is wider than the width, W_O, of the base opening **44**.

[0090] The protrusions **32** may be of any suitable shape. Since the protrusions **32** are three-dimensional, describing their shape depends on the angle from which they are viewed. When viewed from above (that is, perpendicular to the plane of the web, or plan view) such as in FIG. **5**, suitable shapes include, but are not limited to: circular, diamond-shaped, rounded diamond-shaped, U.S. football-shaped, oval-shaped, clover-shaped, triangle-shaped, tear-drop shaped, and elliptical-shaped. (The base openings **44** will typically have a shape similar to the plan view shape of the protrusions **32**.) In other cases, the protrusions **32** (and base openings **44**) may be non-circular. The protrusions **32** may have similar plan view dimensions in all directions, or the protrusions may be longer in one dimension than another. That is, the protrusions **32** may have different length and width dimensions. If the protrusions **32** have a different length than width, the longer dimension will be referred to as the length of the protrusions. The protrusions **32** may, thus, have a ratio of length to width, or an aspect ratio. The aspect ratios can range from about 1:1 to about 10:1.

[0091] As shown in FIG. **5**, the protrusions **32** may have a width, W, that varies from one end **60** to the opposing end **60** when the protrusions are viewed in plan view. The width W may vary with the widest portion of the protrusions in the middle of the protrusions, and the width of the protrusions decreasing at the ends **60** of the protrusions. In other cases, the protrusions **32** could be wider at one or both ends **60** than in the middle of the protrusions. In still other cases, protrusions **32** can be formed that have substantially the same width from one end of the protrusion to the other end of the protrusion. If the width of the protrusions **32** varies along the length of the protrusions, the portion of the protrusion where the width is the greatest is used in determining the aspect ratio of the protrusions.

[0092] When the protrusions **32** have a length L that is greater than their width W, the length of the protrusions may be oriented in any suitable direction relative to the nonwoven material **30**. For example, the length of the protrusions **32** (that is, the longitudinal axis, LA, of the protrusions) may be oriented in the machine direction, the cross-machine direction, or any desired orientation between the machine direction and the cross-machine direction. The protrusions **32** also have a transverse axis TA generally orthogonal to the longitudinal axis LA in the MD-CD plane. In the embodiment shown in FIGS. **5** and **6**, the longitudinal axis LA is parallel to the MD. In some embodiments, all the spaced apart protrusions **32** may have generally parallel longitudinal axes LA.

[0093] The protrusions **32** may have any suitable shape when viewed from the side. Suitable shapes include those in which there is a distal portion or "cap" with an enlarged dimension and a narrower portion at the base when viewed from at least one side. The term "cap" is analogous to the cap portion of a mushroom. (The cap does not need to resemble that of any particular type of mushroom. In addition, the protrusions **32** may, but need not, have a mushroom-like stem portion.) In some cases, the protrusions **32** may be referred to as having a bulbous shape when viewed from the end **60**, such as in FIG. **11**. The term "bulbous", as used herein, is intended to refer to the configuration of the protrusions **32** as having a cap **52** with an enlarged dimension and a narrower portion at the base when viewed from at least one side (particularly when viewing from one of the shorter ends **60**) of the protrusion **32**. The term "bulbous" is not limited to protrusions that have a circular or round plan view configuration that is joined to a columnar portion. The bulbous shape, in the embodiment shown (where the longitudinal axis LA of the deformations **32** is oriented in the machine direction), may be most apparent if a section is taken along the transverse axis TA of the deformation (that is, in the cross-machine direction). The bulbous shape may be less apparent if the deformation is viewed along the length (or longitudinal axis LA) of the deformation such as in FIG. **8**.

[0094] The protrusions **32** may comprise fibers **38** that at least substantially surround the sides of the protrusions. This means that there are multiple fibers that extend (e.g., in the Z-direction) from the base **50** of the protrusions **32** to the distal end **54** of the protrusions, and contribute to form a portion of the sides **56** and cap **52** of a protrusion. The phrase "substantially surround" does not require that each individual fiber be wrapped in the X-Y plane substantially or completely around the sides of the protrusions. If the fibers **38** are located completely around the sides of the protrusions, this would mean that the fibers are located 360° around the protrusions. The protrusions **32** may be free of large openings at their ends **60**, such as those openings **18** at the leading end and trailing end of the tufts shown in FIG. **1**. The protrusions **32** also differ from embossed structures such as shown in FIG. **4**. Embossed structures typically do not have distal portions that are spaced perpendicularly away (that is, in the Z-direction) from their base that are wider than portions that are adjacent to their base, as in the case of the cap **52** on the present protrusions **32**.

[0095] The protrusions **32** may have certain additional characteristics. As shown in FIGS. **11** and **12**, the protrusions **32** may be substantially hollow. As used herein, the term "substantially hollow" refers to structures which the protrusions **32** are substantially free of fibers in interior of protrusions. The term "substantially hollow", does not, however, require that the interior of the protrusions must be completely free of fibers. Thus, there can be some fibers inside the protrusions. "Substantially hollow" protrusions are distinguishable from filled three-dimensional structures, such as those made by laying down fibers, such as by airlaying or carding fibers onto a forming structure with recesses therein.

[0096] The side walls **56** of the protrusions **32** can have any suitable configuration. The configuration of the side walls **56**, when viewed from the end of the protrusion such as in FIG. **11**, can be linear or curvilinear, or the side walls can be formed by a combination of linear and curvilinear portions. The curvilinear portions can be concave, convex, or combinations of both. For example, the side walls **56** in the embodiment show in FIG. **11**, comprise portions that are curvilinear concave inwardly near the base of the protrusions and convex outwardly near the cap of the protrusions. The sidewalls **56** and the area around the base opening **44** of the protrusions may, under 20× magnification, have a visibly significantly lower concentration of fibers per given area (which may be evidence of a lower basis weight or lower opacity) than the portions of the nonwoven in the unformed first region **40**. The protrusions **32** may also have thinned fibers in the sidewalls **56**. The fiber thinning, if present, will be apparent in the form of necked regions in the fibers **38** as seen in scanning electron microscope (SEM) images taken at 200× magnification. Thus, the fibers may have a first cross-sectional area when they are in the undeformed nonwoven precursor web, and a second cross-sectional area in the side walls **56** of the protrusions **32** of the deformed nonwoven web, wherein the first cross-sectional area is greater than the second cross-sectional area. The side walls **56** may also comprise some broken fibers as well.

[0097] In some embodiments, the distal end **54** of the protrusions **32** may be comprised of original basis weight, non-thinned, and non-broken fibers. If the base opening **44** faces upward, the distal end **54** will be at the bottom of the depression that is formed by the protrusion. The distal end **54** will be free from apertures formed completely through the distal end. Thus, the nonwoven materials may be nonapertured. The term "apertures", as used herein, refers to holes formed in the nonwovens after the formation of the nonwovens, and does not include the pores typically present in nonwovens. The term "apertures" also does not refer to irregular breaks (or interruptions) in the nonwoven material(s) such as shown in FIGS. **15**D-**15**F and FIG. **20** resulting from localized tearing of the material(s) during the process of forming deformations therein, which breaks may be due to variability in the precursor material(s). The distal end **54** may have relatively greater fiber concentration or density in comparison to the remaining portions of the structure that forms the protrusions. As described in greater detail below, however, if the nonwoven web is comprised of more than one layer, the concentration of fibers in the different portions of the protrusions may vary between the different layers.

[0098] The protrusions **32** may be of any suitable size. The size of the protrusions **32** can be described in terms of protrusion length, width, caliper, height, depth, cap size, and opening size. (Unless otherwise stated, the length L and width W of the protrusions are the exterior length and width of the cap **52** of the protrusions.) The dimensions of the protrusions and openings can be measured before and after compression (under either a pressure of 7 kPa or 35 KPa, whichever is specified) in accordance with the Accelerated Compression Method described in the Test Methods section. The protrusions have a caliper that is measured between the same points as the height H, but under a 2 KPa load, in accordance with the Accelerated Compression Method. All dimensions of the protrusions and openings other than caliper (that is, length, width, height, depth, cap size, and opening size) are measured without pressure applied at the time of making the measurement using a microscope at 20× magnification.

[0099] In some embodiments, the length of the cap **52** may be in a range from about 1.5 mm to about 10 mm. In some embodiments, the width of the cap (measured where the width is the greatest) may be in a range from about 1.5 mm to about 5 mm. The cap portion of the protrusions may have a plan view surface area of at least about 3 mm^2. In some embodiments, the protrusions may have a pre-compression height H that is in a range from about 1 mm to about 10 mm, alternatively from about 1 mm to about 6 mm. In some embodiments, the protrusions may have a post-compression height H that is in a range from about 0.5 mm to about 6 mm, alternatively from about 0.5 mm to about 1.5 mm. In some embodiments, the protrusions may have a depth D, in an uncompressed state that is in a range from about 0.5 mm to about 9 mm, alternatively from about 0.5 mm to about 5 mm. In some embodiments, the protrusions may have a depth D, after compression that is in a range from about 0.25 mm to about 5 mm, alternatively from about 0.25 mm to about 1 mm.

[0100] The nonwoven material **30** can comprise a composite of two or more nonwoven materials that are joined together. In such a case, the fibers and properties of the first layer will be designated accordingly (e.g., the first layer is comprised of a first plurality of fibers), and the fibers and properties of the second and subsequent layers will be designated accordingly (e.g., the second layer is comprised of a second plurality of fibers). In a two or more layer structure, there are a number of possible configurations the layers may take following the formation of the deformations therein. These will often depend on the extensibility of the nonwoven materials used for the layers. It is desirable that at least one of the layers have deformations which form protrusions **32** as described herein in which, along at least one cross-section, the width of the cap **52** of the protrusions is greater than the width of the base opening **44** of the deformations. For example, in a two layer structure where one of the layers will serve as the topsheet of an absorbent article and the other layer will serve as an underlying layer (such as an acquisition layer), the layer that has protrusions therein may comprise the topsheet layer. The layer that most typically has a bulbous shape will be the one which is in contact with the male forming member during the process of deforming the web. FIG. **15**A-FIG. **15**E show different alternative embodiments of three-dimensional protrusions **32** in multiple layer materials.

[0101] In certain embodiments, such as shown in FIGS. **11**, **12**, and **15**A, similar-shaped looped fibers may be formed in each layer of multiple layer nonwoven materials, including in the layer **30**A that is spaced furthest from the discrete male forming elements during the process of forming the protrusions therein, and in the layer **30**B that is closest to the male forming elements during the process. One layer such as **30**B fits within the other layer, such as **30**A. These layers may be referred to as a "nested" structure. Formation of a nested structure may require the use of two (or more) highly extensible nonwoven precursor webs. In the case of two layer materials, nested structures may form two complete loops, or (as shown in some of the following drawing figures) two incomplete loops of fibers.

[0102] As shown in FIG. **15**A, a three-dimensional protrusion **32** comprises protrusions **32**A formed in the first layer **30**A and protrusions **32**B formed in the second layer **30**B. In one embodiment, the first layer **30**A may be incorporated into an absorbent article as an acquisition layer, and the second layer **30**B may be a topsheet, and the protrusions formed by the two layers may fit together (that is, are nested). In this embodiment, the protrusions **32**A and **32**B formed by the first and second layers **30**A and **30**B fit closely together. The three-dimensional protrusion **32**A comprises a plurality of fibers **38**A and the three-dimensional protrusion **32**B comprises a plurality of fibers **38**B. The three-dimensional protrusion **32**B is nested into the three-dimensional protrusion **32**A. In the embodiment shown, the fibers **38**A in the first layer **30**A are shorter in length than the fibers **38**B in the second layer **30**B. In other embodiments, the relative length of fibers in the layers may be the same, or in the opposite relationship wherein the fibers in the first layer are longer than those in the second layer. In addition, in this embodiment, and any of the other embodiments described herein, the nonwoven layers can be inverted when incorporated into an absorbent article, or other article, so that the protrusions **32** face upward (or outward). In such a case, the material suitable for the topsheet will be used in layer **30**A, and material suitable for the underlying layer will be used in layer **30**B.

[0103] FIG. **15**B shows that the nonwoven layers need not be in a contacting relationship within the entirety of the protrusion **32**. Thus, the protrusions **32**A and **32**B formed by the first and second layers **30**A and **30**B may have different heights and/or widths. The two materials may have substantially the same shape in the protrusion **32** as shown in FIG. **15**B (where one of the materials has the same the curvature as the other). In other embodiments, however, the layers may have different shapes. It should be understood that FIG. **15**B shows only one possible arrangement of layers, and that many other variations are possible, but that as in the case of all the figures, it is not possible to provide a drawing of every possible variation.

[0104] As shown in FIG. **15**C, one of the layers, such as first layer **30**A (e.g., an acquisition layer) may be ruptured in the area of the three-dimensional protrusion **32**. As shown in FIG. **15**C, the protrusions **32** are only formed in the second layer **30**B (e.g., the topsheet) and extend through openings in the first layer **30**A. That is, the three-dimensional protrusion **32**B in the second layer **30**B interpenetrates the ruptured first layer **30**A. Such a structure may place the topsheet in direct contact an underlying distribution layer or absorbent core, which may lead to improved dryness. In such an embodiment, the layers are not considered to be "nested" in the area of the protrusion. (In the other embodiments shown in FIGS. **15**D-**15**F, the layers would still be considered to be "nested".) Such a structure may be formed if the material of the second layer **30**B is much more extensible than the material of the first layer **30**A. In such a case, the openings can be formed by locally rupturing first precursor web by the process described in detail below. The ruptured layer may have any suitable configuration in the area of the protrusion **32**. Rupture may involve a simple splitting open of first precursor web, such that the opening in the first layer **30**A remains a simple two-dimensional aperture. However, for some materials, portions of the first layer **30**A can be deflected or urged out-of-plane (i.e., out of the plane of the first layer **30**A) to form flaps **70**. The form and structure of any flaps is highly dependent upon the material properties of the first layer **30**A. Flaps can have the general structure shown in FIG. **15**C. In other embodiments, the flaps **70** can have a more volcano-like structure, as if the protrusion **32**B is erupting from the flaps.

[0105] Alternatively, as shown in FIGS. **15**D-**15**F, one or both of the first layer **30**A and the second layer **30**B may be interrupted (or have a break therein) in the area of the three-dimensional protrusion **32**. FIGS. **15**D and **15**E show that the three-dimensional protrusion **32**A of the first layer **30**A may have an interruption **72**A therein. The three-dimensional protrusion **32**B of the non-interrupted second layer **30**B may coincide with and fit together with the three-dimensional protrusion **32**A of the interrupted first layer **30**A. Alternatively, FIG. **15**F shows an embodiment in which both the first and second layers **30**A and **30**B have interruptions, or breaks, therein (**72**A and **72**B, respectively). In this case, the interruptions in the layers **30**A and **30**B are in different locations in the protrusion **32**. FIGS. **15**D-**15**F show unintentional random or inconsistent breaks in the materials typically formed by random fiber breakage, which are generally misaligned and can be in the first or second layer, but are not typically aligned and completely through both layers. Thus, there typically will not be an aperture formed completely through all of the layers at the distal end **54** of the protrusions **32**.

[0106] For dual layer and other multiple layer structures, the basis weight distribution (concentration of fibers) within the deformed material **30** can be different between the layers. As shown in FIG. **16**, the nonwoven layer in contact with the male forming element (e.g., **30**B) may have a large portion at the distal end **54**B of the protrusion **32**B with a similar basis weight to the original nonwoven. As shown in FIG. **17**, the basis weight in the sidewalls **56**B of the protrusion **32**B and near the base opening **44** may be lower than the basis weight of the original material and the distal end **54** of the protrusion **32**B. As shown in FIG. **18**, the nonwoven layer in contact with the female forming element (e.g., **30**A) may, however, have significantly less basis weight in the cap **52**A of the protrusion **32**A than in the original nonwoven. As shown in FIG. **19**, the sidewalls **56**A of the protrusion **32**A may have less basis weight than the original nonwoven, but more basis weight than the distal end **54**A of the protrusion **32**A.

[0107] The base openings **44** can be of any suitable shape and size. The shape of the base opening **44** will typically be similar to, or the same as, the plan view shape of the corresponding protrusions **32**. The base opening **44** may have a width that is greater than about any of the following dimensions before (and after compression): 0.5 mm, 0.7 mm, 0.8 mm, 0.9 mm, 1 mm, or any 0.1 mm increment above 1 mm. The width of the base opening **44** may be in a range that is from any of the foregoing amounts up to about 4 mm, or more. The base openings **44** may have a length that ranges from about 1.5 mm or less to about 10 mm, or more. The base openings **44** may have an aspect ratio that ranges from about 1:1 to 20:1, alternatively from about 1:1 to 10:1. Measurements of the dimensions of the base opening can be made on a photomicrograph. When the size of the width of the base opening **44** is specified herein, it will be appreciated that if the openings are not of uniform width in a particular direction, the width, W_O, is measured at the widest portion as shown in FIG. **6**. The nonwoven materials of the present disclosure and the method of making the same may create deformations with a wider opening than certain prior structures which have a narrow base. This allows the base openings **44** to be more visible to the naked eye. The width of the base opening **44** is of interest because, being the narrowest portion of the opening, it will be most restrictive of the size of the opening. The deformations retain their wide base openings **44** after compression perpendicular to the plane of the first region **40**.

[0108] The deformations may compress under load. In some cases, it may be desirable that the load is low enough so that, if the nonwoven is worn against a wearer's body, with the deformations in contact with the wearer's body, the deformations will be soft and will not imprint the skin. This applies in cases where either the protrusions **32** or the base openings **44** are oriented so that they are in contact with the wearer's body. For example, it may be desirable for the deformations to compress under pressures of 2 kPa or less. In other cases, it will not matter if the deformations imprint the wearer's skin. It may be desirable for at least one of the protrusions **32** in the nonwoven material **30** to collapse or buckle in the controlled manner described below under the 7 KPa load when tested in accordance with the Accelerated Compression Method in the Test Methods section below. Alternatively, at least some, or in other cases, a majority of the protrusions **32** may collapse in the controlled manner described herein. Alternatively, substantially all of the protrusions **32** may collapse in the controlled manner described herein. The ability of the protrusions **32** to collapse may also be measured under a load of 35 kPa. The 7 kPa and 35 kPa loads simulate manufacturing and compression packaging conditions. Wear conditions can range from no or limited pressure (if the wearer is not sitting on the absorbent article) up to 2 kPa, 7 kPa, or more.

[0109] The protrusions **32** may collapse in a controlled manner after compression to maintain the wide opening **44** at the base. FIG. **13** shows the first surface **34** of a nonwoven material **30** according to the present disclosure after it has been subjected to compression. FIG. **14** is a side view of a single downwardly-oriented protrusion **32** after it has been subjected to compression. As shown in FIG. **13**, when the protrusions **32** have been compressed, there appears to be a higher concentration of fibers in the form of a ring of increased opacity **80** around the base opening **44**. When a compressive force is applied to the nonwoven materials, the side walls **56** of the protrusions **32** may collapse in a more desirable/controlled manner such that the side walls **56** become concave and fold into regions of overlapping layers (such as into an s-shape/accordion-shape). The ring of increased opacity **80** represents folded layers of material. In other words, the protrusions **32** may have a degree of dimensional stability in the X-Y plane when a Z-direction force is applied to the protrusions. It is not necessary that the collapsed configuration of the protrusions **32** be symmetrical, only that the collapsed configuration prevent the protrusions **32** from flopping over or pushing back into the original plane of the nonwoven, and significantly reducing the size of the base opening. For example, as shown in FIG. **14**, the left side of the protrusion **32** can form a z-folded structure, and the right side of the protrusion does not, but still appears, when viewed from above, to have higher opacity due to a degree of overlapping of the material in the folded portion. Without wishing to be bound to any particular theory, it is believed that the wide base opening **44** and large cap **52** (greater than the width of the base opening **44**), combined with the lack of a pivot point, causes the protrusions **32** to collapse in a controlled manner (prevents the protrusion **32** from flopping over). Thus, the protrusions **32** are free of a hinge structure that would otherwise permit them to fold to the side when compressed. The large cap **52** also prevents the protrusion **32** from pushing back into the original plane of the nonwoven.

[0110] The deformations can be disposed in any suitable density across the surface of the nonwoven material **30**. The deformations may, for example, be present in a density of: from about 5 to about 100 deformations; alternatively from about 10 to about 50 deformations; alternatively from about 20 to about 40 deformations, in an area of 10 cm^2.

[0111] The deformations can be disposed in any suitable arrangement across the plane of the nonwoven material. Suitable arrangements include, but are not limited to: staggered arrangements, and zones. In some cases, the nonwoven material **30** may comprise both deformations and other features known in the art such as embossments and apertures. The deformations and other features may be in separate zones, be intermixed, or overlap. Intermixed arrangements can be created in any suitable manner. In some cases, intermixed arrangements can be created by using the techniques described in U.S. Patent Publication No. US 2012/0064298 A1, Orr, et al. In other cases, overlapping arrangements can be created by forming the deformations and then subsequently passing the nonwoven web between a forming member having male forming elements thereon and a compliant surface, and applying pressure to the web with the forming member and compliant surface. These techniques for producing overlapping arrangements enable deformations and other features to be combined so they are disposed in different locations on the nonwoven material or they can cause at least some of the deformations and at least some of the other features to be disposed in the same location on the nonwoven material.

[0112] The nonwoven webs **30** described herein can comprise any suitable component or components of an absorbent article. For example, the nonwoven webs can comprise the topsheet of an absorbent article, or as shown in FIG. **25**, if the nonwoven web **30** comprises more than one layer, the nonwoven web can comprise a combined topsheet **84** and acquisition layer **86** of an absorbent article, such as diaper **82**. The diaper **82** shown in FIGS. **25-27** also comprises an absorbent core **88**, a backsheet **94**, and a distribution layer **96**. The nonwoven materials of the present disclosure may also form an outer cover of an absorbent article, such as backsheet **94**. The nonwoven webs **30** can be placed in an absorbent article with the deformations **31** in any suitable orientation. For example, the protrusions **32** can be oriented up or down. In other words, the protrusions **32** may be oriented toward the absorbent core **88** as shown in FIG. **26**. Thus, for example, it may be desirable for the protrusions **32** to point inward toward the absorbent core **88** in a diaper (that is, away from the body-facing side and toward the garment-facing side), or other absorbent article. Alternatively, the protrusions **32** may be oriented so that they extend away from the absorbent core of the absorbent article as shown in FIG. **27**. In still other embodiments, the nonwoven webs **30** can be made so that they have some protrusions **32** that are oriented upward, and some that are oriented downward. Without wishing to be bound to any particular theory, it is believed that such a structure may be useful in that the protrusions that are oriented upward can be more effective for cleaning the body from exudates, while the protrusions that are oriented downward can be more effective for absorption of exudates into the absorbent core. Therefore, without being bound to theory, a combination of these two protrusion orientations will offer advantage that the same product can fulfill the two functions.

[0113] A two or more layer nonwoven structure may provide fluid handling benefits. If the layers are integrated together, and the protrusions **32** are oriented toward the absorbent core, they may also provide a dryness benefit. It may be desirable, on the other hand, for the protrusions **32** to point outward, away from the absorbent core in a pad for a wet or dry mop to provide a cleaning benefit. In some embodiments, when the nonwoven web **30** is incorporated into an absorbent article, the underlying layers can be either substantially, or completely free, of tow fibers. Suitable underlying layers that are free of tow fibers may, for example, comprise a layer or patch of cross-linked cellulose fibers. In some cases, it may be desirable that the nonwoven material **30** is not entangled with (that is, is free from entanglement with) another web.

[0114] The layers of the nonwoven structure (e.g., a topsheet and/or acquisition layer) may be colored. Color may be imparted to the webs by color pigmentation. The term "color pigmentation" encompasses any pigments suitable for imparting a non-white color to a web. This term therefore does not include "white" pigments such as TiO_2 which are typically added to the layers of conventional absorbent articles to impart them with a white appearance. Pigments are usually dispersed in vehicles or substrates for application, as for instance in inks, paints, plastics or other polymeric materials. The pigments may for example be introduced in a polypropylene masterbatch. A masterbatch comprises a high concentration of pigment and/or additives which are dispersed in a carrier medium which can then be used to pigment or modify the virgin polymer material into a pigmented bicomponent nonwoven. An example of suitable colored masterbatch material that can be introduced is Pantone color 270 Sanylen violet PP 42000634 ex Clariant, which is a PP resin with a high concentration of violet pigment. Typically, the amount of pigments introduced by weight of the webs may be of from 0.3%-2.5%. Alternatively, color may be imparted to the webs by way of impregnation of a colorant into the substrate. Colorants such as dyes, pigments, or combinations may be impregnated in the formation of substrates such as polymers, resins, or nonwovens. For example, the colorant may be added to molten batch of polymer during fiber or filament formation.

[0115] Precursor Materials

[0116] The nonwoven materials of the present disclosure can be made of any suitable nonwoven materials ("precursor materials"). The nonwoven webs can be made from a single layer, or multiple layers (e.g., two or more layers). If multiple layers are used, they can be comprised of the same type of nonwoven material, or different types of nonwoven materials. In some cases, the precursor materials may be free of any film layers.

[0117] The fibers of the nonwoven precursor material(s) can be made of any suitable materials including, but not limited to natural materials, synthetic materials, and combinations thereof. Suitable natural materials include, but are not limited to cellulose, cotton linters, bagasse, wool fibers, silk fibers, etc. Cellulose fibers can be provided in any suitable form, including but not limited to individual fibers, fluff pulp, drylap, liner board, etc. Suitable synthetic materials include, but are not limited to nylon, rayon and polymeric materials. Suitable polymeric materials include, but are not limited to: polyethylene (PE), polyester, polyethylene terephthalate (PET), polypropylene (PP), and co-polyester. In some embodiments, however, the nonwoven precursor materials can be either substantially, or completely free, of one or more of these materials. For example, in some embodiments, the precursor materials may be substantially free of cellulose, and/or exclude paper materials. In some embodiments, one or more precursor materials can comprise up to 100% thermoplastic fibers. The fibers in some cases may, therefore, be substantially non-absorbent. In some embodiments, the nonwoven precursor materials can be either substantially, or completely free, of tow fibers.

[0118] The precursor nonwoven materials can comprise any suitable types of fibers. Suitable types of fibers include, but are not limited to: monocomponent, bicomponent, and/or biconstituent, non-round (e.g., shaped fibers (including but not limited to fibers having a trilobal cross-section) and capillary channel fibers). The fibers can be of any suitable size. The fibers may, for example, have major cross-sectional dimensions (e.g., diameter for round fibers) ranging from 0.1-500 microns. Fiber size can also be expressed in denier, which is a unit of weight per length of fiber. The constituent fibers may, for example, range from about 0.1 denier to about 100 denier. The constituent fibers of the nonwoven precursor web(s) may also be a mixture of different fiber types, differing in such features as chemistry (e.g., PE and PP), components (mono- and bi-), shape (i.e. capillary channel and round) and the like.

[0119] The nonwoven precursor webs can be formed from many processes, such as, for example, air laying processes, wetlaid processes, meltblowing processes, spunbonding processes, and carding processes. The fibers in the webs can then be bonded via spunlacing processes, hydroentangling, calendar bonding, through-air bonding and resin bonding. Some of such individual nonwoven webs may have bond sites where the fibers are bonded together.

[0120] The basis weight of nonwoven materials is usually expressed in grams per square meter (gsm). The basis weight of a single layer nonwoven material can range from about 8 gsm to about 100 gsm, depending on the ultimate use of the material **30**. For example, the topsheet of a topsheet/acquisition layer laminate or composite may have a basis weight from about 8 to about 40 gsm or from about 8 to about 30 gsm, or from about 8 to about 20 gsm. The acquisition layer may have a basis weight from about 10 to about 120 gsm or from about 10 to about 100 gsm, or from about 10 to about 80 gsm. The basis weight of a multi-layer material is the combined basis weight of the constituent layers and any other added components. The basis weight of multi-layer materials of interest herein can range from about 20 gsm to about 150 gsm, depending on the ultimate use of the material **30**. The nonwoven precursor webs may have a density that is between about 0.01 and about 0.4 g/cm^3 measured at 0.3 psi (2 KPa).

[0121] The precursor nonwoven webs may have certain desired characteristics. The precursor nonwoven web(s) each have a first surface, a second surface, and a thickness. The first and second surfaces of the precursor nonwoven web(s) may be generally planar. It is typically desirable for the precursor nonwoven web materials to have extensibility to enable the fibers to stretch and/or rearrange into the form of the protrusions. If the nonwoven webs are comprised of two or more layers, it is desirable for all of the layers to be as extensible as possible. Extensibility is desirable in order to maintain at least some non-broken fibers in the sidewalls around the perimeter of the protrusions. It may be desirable for individual precursor webs, or at least one of the nonwovens within a multi-layer structure, to be capable of undergoing an elongation of greater than or equal to about one of the following amounts: 100% (that is double its unstretched length), 110%, 120%, or 130% up to about 200%, or more, at or before reaching the peak tensile force. It is also desirable for the precursor nonwoven webs to be capable of undergoing plastic deformation to ensure that the structure of the deformations is "set" in place so that the nonwoven web will not tend to recover or return to its prior configuration.

[0122] Materials that are not extensible enough (e.g., inextensible PP) may form broken fibers around much of the perimeter of the deformation, and create more of a "hanging chad" **90** (i.e., the cap **52** of the protrusions **32** may be at least partially broken from and separated from the rest of the protrusion (as shown in FIG. **20**). The area on the sides of the protrusion where the fibers are broken is designated with reference number **92**. Materials such as that shown in FIG. **20** will not be suitable for a single layer structure, and, if used, will typically be part of a composite multi-layer structure in which another layer has protrusions **32** as described herein.

[0123] When the fibers of a nonwoven web are not very extensible, it may be desirable for the nonwoven to be underbonded as opposed to optimally bonded. A thermally bonded nonwoven web's tensile properties can be modified by changing the bonding temperature. A web can be optimally or ideally bonded, underbonded or overbonded. Optimally or ideally bonded webs are characterized by the highest peak tensile strength and elongation at tensile peak with a rapid decay in strength after tensile peak. Under strain, bond sites fail and a small amount of fibers pull out of the bond site. Thus, in an optimally bonded nonwoven, the fibers **38** will stretch and break around the bond sites **46** when the nonwoven web is strained beyond a certain point. Often there is a small reduction in fiber diameter in the area surrounding the thermal point bond sites. Underbonded webs have a lower peak tensile strength and elongation at tensile peak when compared to optimally bonded webs, with a slow decay in strength after tensile peak. Under strain, some fibers will pull out from the thermal point bond sites. Thus, in an underbonded nonwoven, at least some of the fibers **38** can be separated easily from the bond sites **46** to allow the fibers **38** to pull out of the bond sites and rearrange when the material is strained. Overbonded webs also have a lowered peak tensile strength and elongation at tensile peak when compared to optimally bonded webs, with a rapid decay in strength after tensile peak. The bond sites look like films and result in complete bond site failure under strain.

[0124] When the nonwoven web comprises two or more layers, the different layers can have the same properties, or any suitable differences in properties relative to each other. In one embodiment, the nonwoven web **30** can comprise a two layer structure that is used in an absorbent article. For convenience, the precursor webs and the material into which they are formed are referred to herein by the same reference numbers. One of the layers, a second layer **30**B, can serve as the topsheet of the absorbent article, and the first layer **30**A can be an underlying layer (or sub-layer) and serve as an acquisition layer. The acquisition layer **30**A receives liquids that pass through the topsheet and distributes them to underlying absorbent layers. In such a case, the topsheet **30**B may be less hydrophilic than sub-layer(s) **30**A, which may lead to better dewatering of the topsheet. In other embodiments, the topsheet can be more hydrophilic than the sub-layer(s). In some cases, the pore size of the acquisition layer may be reduced, for example via using fibers with smaller denier or via increasing the density of the acquisition layer material, to better dewater the pores of the topsheet.

[0125] The second nonwoven layer **30**B that may serve as the topsheet can have any suitable properties. Properties of interest for the second nonwoven layer, when it serves as a topsheet, in addition to sufficient extensibility and plastic deformation may include uniformity and opacity. As used herein, "uniformity" refers to the macroscopic variability in basis weight of a nonwoven web. As used, herein, "opacity" of nonwoven webs is a measure of the impenetrability of visual light, and is used as visual determination of the relative fiber density on a macroscopic scale. As used herein, "opacity" of the different regions of a single nonwoven deformation is determined by taking a photomicrograph at 20× magnification of the portion of the nonwoven containing the deformation against a black background. Darker areas indicate relatively lower opacity (as well as lower basis weight and lower density) than white areas.

[0126] Several examples of nonwoven materials suitable for use as the second nonwoven layer **30**B include, but are not limited to: spunbonded nonwovens; carded nonwovens; and other nonwovens with high extensibility (strain at peak tensile strength in the ranges set forth above) and sufficient plastic deformation to ensure the structure is set and does not have significant recovery. One suitable nonwoven material as a topsheet for a topsheet/acquisition layer composite structure may be an extensible spunbonded nonwoven comprising polypropylene and polyethylene. The fibers can comprise a blend of polypropylene and polyethylene, or they can be bi-component fibers, such as a sheath-core fiber with polyethylene on the sheath and polypropylene in the core of the fiber. Another suitable material is a bi-component fiber spunbonded nonwoven comprising fibers with a polyethylene sheath and a polyethylene/polypropylene blend core.

[0127] The first nonwoven layer **30**A that may, for example, serve as the acquisition layer can have any suitable properties. Properties of interest for the first nonwoven layer, in addition to sufficient extensibility and plastic deformation may include uniformity and opacity. If the first nonwoven layer **30**A serves as an acquisition layer, its fluid handling properties must also be appropriate for this purpose. Such properties may include: permeability, porosity, capillary pressure, caliper, as well as mechanical properties such as sufficient resistance to compression and resiliency to maintain void volume. Suitable nonwoven materials for the first nonwoven layer when it serves as an acquisition layer include, but are not limited to: spunbonded nonwovens; through-air bonded ("TAB") carded nonwoven materials;

spunlace nonwovens; hydroentangled nonwovens; and, resin bonded carded nonwoven materials. Of course, the composite structure may be inverted and incorporated into an article in which the first layer **30**A serves as the topsheet and the second layer **30**B serves as an acquisition layer. In such cases, the properties and exemplary methods of the first and second layers described herein may be interchanged.

[0128] The layers of a two or more layered nonwoven web structure can be combined together in any suitable manner. In some cases, the layers can be unbonded to each other and held together autogenously (that is, by virtue of the formation of deformations therein). For example, both precursor webs **30**A and **30**B contribute fibers to deformations in a "nested" relationship that "locks" the two precursor webs together, forming a multi-layer web without the use or need for adhesives or thermal bonding between the layers. In other embodiments, the layers can be joined together by other mechanisms. If desired an adhesive between the layers, ultrasonic bonding, chemical bonding, resin or powder bonding, thermal bonding, or bonding at discrete sites using a combination of heat and pressure can be selectively utilized to bond certain regions or all of the precursor webs. If adhesives are used, they can be applied in any suitable manner or pattern including, but not limited to: slots, spirals, spray, and curtain coating. Adhesives can be applied in any suitable amount or basis weight including, but not limited to between about 0.5 and about 30 gsm, alternatively between about 2 and about 5 gsm. In addition, the multiple layers may be bonded during processing, for example, by carding one layer of nonwoven onto a spunbond nonwoven and thermal point bonding the combined layers. In some cases, certain types of bonding between layers may be excluded. For example, the layers of the present structure may be non-hydroentangled together.

[0129] When the precursor nonwoven web comprises two or more layers, it may be desirable for at least one of the layers to be continuous, such as in the form of a web that is unwound from a roll. In some embodiments, each of the layers can be continuous. In alternative embodiments, such as shown in FIG. **24**, one or more of the layers can be continuous, and one or more of the layers can have a discrete length. The layers may also have different widths. For example, in making a combined topsheet and acquisition layer for an absorbent article, the nonwoven layer that will serve as the topsheet may be a continuous web, and the nonwoven layer that will serve as the acquisition layer may be fed into the manufacturing line in the form of discrete length (for example, rectangular, or other shaped) pieces that are placed on top of the continuous web. Such an acquisition layer may, for example, have a lesser width than the topsheet layer. The layers may be combined together as described above.

Methods of Making the Nonwoven Materials

[0130] The nonwoven materials are made by a method comprising the steps of: a) providing at least one precursor nonwoven web; b) providing an apparatus comprising a pair of forming members comprising a first forming member and a second forming member; and c) placing the precursor nonwoven web(s) between the forming members and mechanically deforming the precursor nonwoven web(s) with the forming members. The forming members have a machine direction (MD) orientation and a cross-machine direction (CD) orientation.

[0131] The first and second forming members can be plates, rolls, belts, or any other suitable types of forming members. In some embodiments, it may be desirable to modify the apparatus for incrementally stretching a web described in U.S. Pat. No. 8,021,591, Curro, et al. entitled "Method and Apparatus for Incrementally Stretching a Web" by providing the activation members described therein with the forming elements of the type described herein. In the embodiment of the apparatus **100** shown in FIG. **21**, the first and second forming members **102** and **104** are in the form of non-deformable, meshing, counter-rotating rolls that form a nip **106** therebetween. The precursor web(s) is/are fed into the nip **106** between the rolls **102** and **104**. Although the space between the rolls **102** and **104** is described herein as a nip, as discussed in greater detail below, in some cases, it may be desirable to avoid compressing the precursor web(s) to the extent possible.

[0132] First Forming Member.

[0133] The first forming member **102** has a surface comprising a plurality of first forming elements which comprise discrete, spaced apart male forming elements **112**. The male forming elements are spaced apart in the machine direction and in the cross-machine direction. The term "discrete" does not include continuous or non-discrete forming elements such as the ridges and grooves on corrugated rolls (or "ring rolls") which have ridges that may be spaced apart in one, but not both, of the machine direction and in the cross-machine direction.

[0134] As shown in FIG. **22**, the male forming elements **112** have a base **116** that is joined to (in this case is integral with) the first forming member **102**, a top **118** that is spaced away from the base, and sides **120** that extend between the base and the top of the male forming elements. The male elements **112** also have a plan view periphery, and a height H_1 (the latter being measured from the base **116** to the top **118**). The discrete elements on the male roll have a top **118** with a relatively large surface area (e.g., from about 1 mm to about 10 mm in width, and from about 1 mm to about 20 mm in length) for creating a wide deformation. The male elements **112** may have any suitable configuration. In one embodiment, the male elements **112** have a flat top **118**, vertical sidewalls **120**, a radiused edge forming the transition **122** between the flat top **118** and vertical sidewalls **120** (by vertical side walls, it is meant that the side walls **120** have zero degree side wall angles relative to the perpendicular from the base of the side wall). The top **118** of the male elements **112** may have any suitable plan view configuration, including but not limited to: a rounded diamond configuration as shown in FIGS. **21** and **22**, and an American football-like shape, triangle, clover, teardrop, oval, elliptical.

[0135] Numerous other embodiments of the male forming elements **112** are possible. In other embodiments, the top **118** of the male forming elements **112** can be rounded. In other embodiments, the side walls **120** can be tapered inwardly toward the center of the male forming elements **112** so that the side walls form an angle greater than zero. In other embodiments, the top **118** of the male elements **112** can be of different shapes from those shown in the drawings. In other embodiments, the male forming elements **112** can be disposed in other orientations on the first forming member **102** rather than having their length oriented in the machine direction (including CD-orientations, and orientations between the MD and CD).

[0136] Second Forming Member.

[0137] As shown in FIG. **21**, the second forming member **104** has a surface **124** having a plurality of cavities or recesses

114 therein. The recesses 114 are aligned and configured to receive the male forming elements 112 therein. Thus, the male forming elements 112 mate with the recesses 114 so that a single male forming element 112 fits within the periphery of a single recess 114, and at least partially within the recess 114 in the z-direction. The recesses 114 have a plan view periphery 126 that is larger than the plan view periphery of the male elements 112. As a result, the recess 114 on the female roll completely encompasses the discrete male element 112 when the rolls 102 and 104 are intermeshed. The recesses 114 have a depth D_1 shown in FIG. 23. In some cases, the depth D_1 of the recesses may be greater than the height H_1 of the male forming elements 112.

[0138] The recesses 114 may have a similar plan view configuration as the male elements 112, side walls 128, and an edge 130 around the bottom 132 of the recesses where the side walls 128 meet the bottom 132 of the recesses. The side walls 128 of the recesses 114 may be vertical. The edge 130 of the recesses may be sharp or rounded.

[0139] As discussed above, the recesses 114 may be deeper than the height H_1 of the male elements 112 so the nonwoven material is not nipped (or squeezed) between the male and female rolls 102 and 104 to the extent possible. However, it is understood that passing the precursor web(s) between two rolls with a relatively small space therebetween will likely apply some shear and compressive forces to the web(s). The present method, however, differs from some embossing processes in which the top of the male elements compress the material to be embossed against the bottom of the female elements, thereby increasing the density of the region in which the material is compressed.

[0140] The depth of engagement (DOE) is a measure of the level of intermeshing of the forming members. As shown in FIG. 23, the DOE is measured from the top 118 of the male elements 112 to the outermost surface 124 of the female forming member 114 (e.g., the roll with recesses). The DOE should be sufficiently high, when combined with extensible nonwoven materials, to create protrusions 32 having a distal portion or cap 52 with a maximum width that is greater than the width of the base opening 44. The DOE may, for example, range from at least about 1.5 mm, or less, to about 5 mm, or more. In certain embodiments, the DOE may be between about 2.5 mm to about 5 mm, alternatively between about 3 mm and about 4 mm. The formation of protrusions 32 having a distal portion with a maximum width that is greater than the width of the base opening 44 is believed to differ from most embossing processes in which the embossments typically take the configuration of the embossing elements, which have a base opening that is wider than the remainder of the embossments. As shown in FIG. 23, there is a clearance, C, between the sides 120 of the male elements 112 and the sides (or side walls) 128 of the recesses 114. The clearance, C, between the male and female roll may be the same, or it may vary slightly around the perimeter of the male element. Clearances can range from about 0.005 inches (0.13 mm) to about 0.05 inches (1.3 mm). The clearances and the DOE's are related such that larger clearances can permit higher DOE's to be used.

[0141] The precursor nonwoven web is placed between the forming members 102 and 104. The precursor nonwoven web can be placed between the forming members with either side of the precursor web (first surface 34 or second surface 36) facing the first forming member, male forming member 102. For convenience of description, the second surface 36 of the precursor nonwoven web will be described herein as being placed in contact with the first forming member 102. (Of course, in other embodiments, the second surface 36 of the precursor nonwoven web can be placed in contact with the second forming member 104.) The precursor material is mechanically deformed with the forming members 102 and 104 when a force is applied on the nonwoven web with the forming members 102 and 104. The force can be applied in any suitable manner. If the forming members 102 and 104 are in the form of plates, the force will be applied when the plates are brought together. If the forming members 102 and 104 are in the form of counter-rotating rolls (or belts, or any combination of rolls and belts), the force will be applied when the precursor nonwoven web passes through the nip between the counter-rotating elements. The force applied by the forming members impacts the precursor web and mechanically deforms the precursor nonwoven web.

[0142] When deforming multiple webs that are laminated together with an adhesive, it may be desirable to chill the forming members in order to avoid glue sticking to and fouling the forming members. The forming members can be chilled using processes know in the art. One such process could be an industrial chiller that utilizes a coolant, such as propylene glycol. In some cases, it may be desirable to operate the process in a humid environment such that a layer of condensate forms on the forming members.

[0143] The precursor nonwoven web forms nonwoven web comprising a generally planar first region and a plurality of discrete integral second regions that comprise deformations comprising protrusions extending outward from the first surface 34 of the nonwoven web and openings in the second surface of the nonwoven web. (Of course, if the second surface 36 of the precursor nonwoven web is placed in contact with the second forming member 104, the protrusions will extend outward from the second surface of the nonwoven web and the openings will be formed in the first surface of the nonwoven web.) Without wishing to be bound by any particular theory, it is believed that the extensibility of the precursor web (or at least one of the layers of the same) when pushed by the male forming elements 112 into the recesses 114 with depth of engagement DOE being less than the depth D_1 of the recesses, stretches a portion of the nonwoven web to form a deformation comprising a protrusion with the enlarged cap and wide base opening described above. (This can be analogized to sticking one's finger into an uninflated balloon to stretch and permanently deform the material of the balloon.)

[0144] In cases in which the precursor nonwoven material 30 comprises more than one layer, and one of the layers is in the form of discrete pieces of nonwoven material, as shown in FIG. 24, it may be desirable for the deformations to be formed so that the base openings are in the continuous layer (such as 30B) and the protrusions 32 extend toward the discrete layer (such as 30A). Of course, in other embodiments, the deformations in such a structure can be in the opposite orientation. The deformations can be distributed in any suitable manner over the surfaces of such continuous and discrete layers. For example, the deformations can: be distributed over the full length and/or width of the continuous layer; be distributed in an area narrower than the width of the continuous layer; or be limited to the area of the discrete layer.

[0145] The method of making the nonwoven materials described herein may exclude (or be distinguishable from) the following processes: hydroforming (hydroentangling); hydromolding; use of air jets; rigid-to-resilient (e.g., steel/rubber) embossing; and the use of a patterned surface against a flat anvil surface. The method may also exclude (or be distinguishable from) The Procter & Gamble Company's processes for making Structural Elastic-Like Films ("SELF" processes). The forming members used herein differ from the forming members used in SELFing processes to form corrugated structures (and tufted structures) in that the SELF teeth typically have a comparatively small diameter tip, and the ridges of the mating ring roll only border the SELF teeth on the sides, and not the front and back of the teeth.

Absorbent Articles

[0146] Three-dimensional nonwoven materials and the method of their manufacture of the present disclosure have been discussed above. The use of those three-dimensional nonwoven materials is now explained in further detail in the context of example absorbent articles.

General Description of an Absorbent Article

[0147] An example absorbent article in the form of a diaper **220** is represented in FIGS. **28-30**. FIG. **28** is a plan view of the example diaper **220**, in a flat, laid-out state, with portions of the structure being cut-away to more clearly show the construction of the diaper **220**. The wearer-facing surface of the diaper **220** of FIG. **28** is facing the viewer. This diaper **220** is shown for illustration purpose only as the three-dimensional nonwoven materials of the present disclosure may be used as one or more components of an absorbent article, such as the topsheet, the acquisition layer, the topsheet and the acquisition layer individually, or the topsheet and the acquisition layer as a laminate. In any event the three-dimensional nonwoven materials of the present disclosure may be liquid permeable.

[0148] The absorbent article **220** may comprise a liquid permeable material or topsheet **224**, a liquid impermeable material or backsheet **225**, an absorbent core **228** positioned at least partially intermediate the topsheet **224** and the backsheet **225**, and barrier leg cuffs **234**. The absorbent article may also comprise an ADS **250**, which in the example represented comprises a distribution layer **254** and an acquisition layer **252**, which will be further discussed below. The absorbent article **220** may also comprise elasticized gasketing cuffs **232** comprising elastics **233** joined to a chassis of the absorbent article, typically via the topsheet and/or backsheet, and substantially planar with the chassis of the diaper.

[0149] FIGS. **28** and **31** also show typical taped diaper components such as a fastening system comprising tabs **242** attached towards the rear edge of the article and cooperating with a landing zone **244** on the front of the absorbent article. The absorbent article may also comprise other typical elements, which are not represented, such as a rear elastic waist feature, a front elastic waist feature, transverse barrier cuff(s), and/or a lotion application, for example.

[0150] The absorbent article **220** comprises a front waist edge **210**, a rear waist edge **212** longitudinally opposing the front waist edge **210**, a first side edge **203**, and a second side edge **204** laterally opposing the first side edge **203**. The front waist edge **210** is the edge of the article which is intended to be placed towards the front of the user when worn, and the rear waist edge **212** is the opposite edge. The absorbent article **220** may have a longitudinal axis **280** extending from the lateral midpoint of the front waist edge **210** to a lateral midpoint of the rear waist edge **212** of the article and dividing the article in two substantially symmetrical halves relative to the longitudinal axis **280**, with the article placed flat, laid-out and viewed from above as in FIG. **28**. The absorbent article **220** may also have a lateral axis **290** extending from the longitudinal midpoint of the first side edge **203** to the longitudinal midpoint of the second side edge **204**. The length, L, of the article may be measured along the longitudinal axis **280** from the front waist edge **210** to the rear waist edge **212**. The width, W, of the absorbent article may be measured along the lateral axis **290** from the first side edge **203** to the second side edge **204**. The absorbent article may comprise a crotch point C defined herein as the point placed on the longitudinal axis at a distance of two fifth (⅖) of L starting from the front edge **210** of the article **220**. The article may comprise a front waist region **205**, a rear waist region **206**, and a crotch region **207**. The front waist region **205**, the rear waist region **206**, and the crotch region **207** may each define ⅓ of the longitudinal length, L, of the absorbent article.

[0151] The topsheet **224**, the backsheet **225**, the absorbent core **228**, and the other article components may be assembled in a variety of configurations, in particular by gluing or heat embossing, for example.

[0152] The absorbent core **228** may comprise an absorbent material comprising at least 80% by weight, at least 85% by weight, at least 90% by weight, at least 95% by weight, or at least 99% by weight of superabsorbent polymers, and a core wrap enclosing the superabsorbent polymers. The core wrap may typically comprise two materials, substrates, or nonwoven materials **216** and **216'** for the top side and the bottom side of the core. These types of cores are known as airfelt-free cores. The core may comprise one or more channels, represented in FIG. **28** as the four channels **226**, **226'** and **227**, **227'**. The channels **226**, **226'**, **227**, and **227'** are optional features. Instead, the core may not have any channels or may have any number of channels.

[0153] These and other components of the example absorbent articles will now be discussed in more details.

Topsheet

[0154] In the present disclosure, the topsheet (the portion of the absorbent article that contacts the wearer's skin and receives the fluids) may be formed of a portion of, or all of, one or more of the three-dimensional nonwoven materials described herein and/or have one or more of the nonwoven materials positioned thereon and/or joined thereto, so that the nonwoven material(s) contact(s) the wearer's skin. Other portions of the topsheet (other than the three-dimensional nonwoven materials) may also contact the wearer's skin. The three-dimensional nonwoven materials may be positioned as a strip or a patch on top of the typical topsheet **224**. Alternatively, the three-dimensional nonwoven material may only form a central CD area of the topsheet. The central CD area may extend the full MD length of the topsheet or less than the full MD length of the topsheet.

[0155] The topsheet **224** may be joined to the backsheet **225**, the absorbent core **228** and/or any other layers as is known to those of skill in the art. Usually, the topsheet **224** and the backsheet **225** are joined directly to each other in some locations (e.g., on or close to the periphery of the absorbent article) and are indirectly joined together in other locations by directly joining them to one or more other elements of the article **220**.

[0156] The topsheet **224** may be compliant, soft-feeling, and non-irritating to the wearer's skin. Further, a portion of, or all of, the topsheet **224** may be liquid permeable, permitting liquids to readily penetrate through its thickness. Any portion of the topsheet **224** may be coated with a lotion and/or a skin care composition as is generally disclosed in the art. The topsheet **224** may also comprise or be treated with antibacterial agents.

Backsheet

[0157] The backsheet **225** is generally that portion of the absorbent article **220** positioned adjacent the garment-facing surface of the absorbent core **228** and which prevents, or at least inhibits, the fluids and bodily exudates absorbed and contained therein from soiling articles such as bedsheets and undergarments. The backsheet **225** is typically impermeable, or at least substantially impermeable, to fluids (e.g., urine). The backsheet may, for example, be or comprise a thin plastic film such as a thermoplastic film having a thickness of about 0.012 mm to about 0.051 mm. Other suitable backsheet materials may include breathable materials which permit vapors to escape from the absorbent article **220**, while still preventing, or at least inhibiting, fluids from passing through the backsheet **225**.

[0158] The backsheet **225** may be joined to the topsheet **224**, the absorbent core **228**, and/or any other element of the absorbent article **220** by any attachment methods known to those of skill in the art.

[0159] An outer cover **223** of the absorbent article **220** may cover at least a portion of, or all of, the backsheet **225** to form a soft garment-facing surface of the absorbent article. The outer cover **223** may be formed of the high loft, three-dimensional nonwoven materials described herein. Alternatively, the outer cover **223** may comprise one or more known outer cover materials. If the outer cover **223** comprises one of the three-dimensional nonwoven materials of the present disclosure, the three-dimensional nonwoven material of the outer cover **223** may or may not match (e.g., same material, same pattern) a three-dimensional nonwoven material used as the topsheet or the topsheet and the acquisition layer of the absorbent article. In other instances, the outer cover may have a printed or otherwise applied pattern that matches or visually resembles the pattern of the three-dimensional nonwoven materials used as the topsheet or the topsheet and the acquisition layer laminate of the absorbent article. The outer cover **223** is illustrated in dash in FIG. **29**, as an example. The outer cover **223** may be joined to at least a portion of the backsheet **225** through mechanical bonding, adhesive bonding, or other suitable methods of attachment.

Absorbent Core

[0160] The absorbent core is the component of the absorbent article that has the most absorbent capacity and that comprises an absorbent material and a core wrap or core bag enclosing the absorbent material. The absorbent core does not include the acquisition and/or distribution system or any other components of the absorbent article which are not either integral part of the core wrap or core bag or placed within the core wrap or core bag. The absorbent core may comprise, consist essentially of, or consist of, a core wrap, an absorbent material (e.g., superabsorbent polymers and little or no cellulose fibers) as discussed, and glue. In other instances, the absorbent material may comprise a mixture of superabsorbent polymers and air-felt or cellulose fibers. This mixture of superabsorbent polymers and air-felt or cellulose fibers may be positioned within the core bag. The core bag may form a C-wrap around the mixture or may be otherwise formed. Glue may also be present within the core bag to at least partially hold the mixture in place during manufacture and wear.

[0161] The absorbent core **228** may comprise an absorbent material with a high amount of superabsorbent polymers (herein abbreviated as "SAP") enclosed within the core wrap. The SAP content may represent 70%-100% or at least 70%, 75%, 80%, 85%, 90%, 95%, 99%, or 100%, by weight of the absorbent material, contained in the core wrap. The core wrap is not considered as absorbent material for the purpose of assessing the percentage of SAP in the absorbent core.

[0162] By "absorbent material" it is meant a material which has some absorbency property or liquid retaining properties, such as SAP, cellulosic fibers as well as synthetic fibers. Typically, glues used in making absorbent cores have no or little absorbency properties and are not considered as absorbent material. The SAP content may be higher than 80%, for example at least 85%, at least 90%, at least 95%, at least 99%, and even up to and including 100% of the weight of the absorbent material contained within the core wrap. This airfelt-free core is relatively thin compared to a conventional core typically comprising between 40-60% SAP by weight and a high content of cellulose fibers. The absorbent material may in particular comprises less than 15% weight percent or less than 10% weight percent of natural, cellulosic, or synthetic fibers, less than 5% weight percent, less than 3% weight percent, less than 2% weight percent, less than 1% weight percent, or may even be substantially free of natural, cellulosic, and/or synthetic fibers.

[0163] As referenced above, the airfelt-free cores with very little or no natural, cellulosic and/or synthetic fibers are quite thin compared to conventional cores, thereby making the overall absorbent article thinner than absorbent articles with cores comprising mixed SAP and cellulosic fibers (e.g., 40-60% cellulose fibers). This core thinness can lead to consumer perceptions of reduced absorbency and performance, although technically this is not the case. Presently, these thin cores have typically been used with substantially planer or apertured topsheets. Furthermore, absorbent articles having these thin airfelt-free cores have reduced capillary void space since there is little or no natural, cellulosic, or synthetic fibers in the cores. Thus, there may sometimes not be enough capillary void space in the absorbent article to fully accept multiple insults of bodily exudates or a single large insult.

[0164] To solve such problems, the present disclosure provides absorbent articles with these thin airfelt-free cores in combination with one of the high-loft, three-dimensional nonwoven materials described herein as a topsheet, an acquisition layer, or as a topsheet and acquisition layer laminate. In such an instance, consumer perception of absorbency and performance, through the increased thickness of the absorbent article owing to the additional thickness provided by the high-loft, three-dimensional nonwoven material, is increased. Furthermore, the three-dimensional nonwoven materials, when used with these thin airfelt-free cores and as the topsheet, the acquisition layer, or the topsheet and acquisition layer laminate, add capillary void space back into the absorbent articles, while still allowing for minimal stack heights, thereby passing cost savings onto consumers and manufactures. As such, the absorbent articles of the present disclosure may easily absorb multiple bodily exudate insults or single large insults owing to this increased capillary void space. Additionally, absorbent articles that comprise the nonwoven materials as the topsheet, the acquisition layer, or the topsheet and acquisition layer laminate provide consumers with an aesthetically pleasing topsheet relative to a planer topsheet or an apertured topsheet with an increased thickness and thus the consumer perceptions of absorbency and performance.

[0165] The example absorbent core **228** of the absorbent article **220** of FIGS. **31-32** is shown in isolation in FIGS. **33-35**. The absorbent core **228** may comprises a front side **480**, a rear side **482**, and two longitudinal sides **484**, **486** joining the front side **480** and the rear side **482**. The absorbent core **228** may also comprise a generally planar top side and a generally planar bottom side. The front side **480** of the core is the side of the core intended to be placed towards the front waist edge **210** of the absorbent article. The core **228** may have a longitudinal axis **280'** corresponding substantially to the longitudinal axis **280** of the absorbent article **220**, as seen from the top in a planar view as in FIG. **28**. The absorbent material may be distributed in higher amount towards the front side **480** than towards the rear side **482** as more absorbency may be required at the front in particular absorbent articles. The front and rear sides **480** and **482** of the core may be shorter than the longitudinal sides **484** and **486** of the core. The core wrap may be formed by two nonwoven materials, substrates, laminates, or other materials, **216**, **216'** which may be at least partially sealed along the sides **484**, **486** of the absorbent core **228**. The core wrap may be at least partially sealed along its front side **480**, rear side **482**, and two longitudinal sides **484**, **486** so that substantially no absorbent material leaks out of the absorbent core wrap. The first material, substrate, or nonwoven **216** may at least partially surround the second material, substrate, or nonwoven **216'** to form the core wrap, as illustrated in FIG. **34**. The first material **216** may surround a portion of the second material **216'** proximate to the first and second side edges **484** and **486**.

[0166] The absorbent core may comprise adhesive, for example, to help immobilizing the SAP within the core wrap and/or to ensure integrity of the core wrap, in particular when the core wrap is made of two or more substrates. The adhesive may be a hot melt adhesive, supplied, by H.B. Fuller, for example. The core wrap may extend to a larger area than strictly needed for containing the absorbent material within.

[0167] The absorbent material may be a continuous layer present within the core wrap. Alternatively, the absorbent material may be comprised of individual pockets or stripes of absorbent material enclosed within the core wrap. In the first case, the absorbent material may be, for example, obtained by the application of a single continuous layer of absorbent material. The continuous layer of absorbent material, in particular of SAP, may also be obtained by combining two absorbent layers having discontinuous absorbent material application patterns, wherein the resulting layer is substantially continuously distributed across the absorbent particulate polymer material area, as disclosed in U.S. Pat. Appl. Pub. No. 2008/0312622A1 (Hundorf), for example. The absorbent core **228** may comprise a first absorbent layer and a second absorbent layer. The first absorbent layer may comprise the first material **216** and a first layer **261** of absorbent material, which may be 100% or less of SAP. The second absorbent layer may comprise the second material **216'** and a second layer **262** of absorbent material, which may also be 100% or less of SAP. The absorbent core **228** may also comprise a fibrous thermoplastic adhesive material **251** at least partially bonding each layer of absorbent material **261**, **262** to its respective material **216** or **216'**. This is illustrated in FIGS. **34-35**, as an example, where the first and second SAP layers have been applied as transversal stripes or "land areas" having the same width as the desired absorbent material deposition area on their respective substrate before being combined. The stripes may comprise different amounts of absorbent material (SAP) to provide a profiled basis weight along the longitudinal axis of the core **280**. The first material **216** and the second material **216'** may form the core wrap.

[0168] The fibrous thermoplastic adhesive material **251** may be at least partially in contact with the absorbent material **261**, **262** in the land areas and at least partially in contact with the materials **216** and **216'** in the junction areas. This imparts an essentially three-dimensional structure to the fibrous layer of thermoplastic adhesive material **251**, which in itself is essentially a two-dimensional structure of relatively small thickness, as compared to the dimension in length and width directions. Thereby, the fibrous thermoplastic adhesive material may provide cavities to cover the absorbent material in the land areas, and thereby immobilizes this absorbent material, which may be 100% or less of SAP.

[0169] The thermoplastic adhesive used for the fibrous layer may have elastomeric properties, such that the web formed by the fibers on the SAP layer is able to be stretched as the SAP swell.

Superabsorbent Polymer (SAP)

[0170] The SAP useful with the present disclosure may include a variety of water-insoluble, but water-swellable polymers capable of absorbing large quantities of fluids.

[0171] The superabsorbent polymer may be in particulate form so as to be flowable in the dry state. Particulate absorbent polymer materials may be made of poly(meth)acrylic acid polymers. However, starch-based particulate absorbent polymer material may also be used, as well as polyacrylamide copolymer, ethylene maleic anhydride copolymer, cross-linked carboxymethylcellulose, polyvinyl alcohol copolymers, cross-linked polyethylene oxide, and starch grafted copolymer of polyacrylonitrile.

[0172] The SAP may be of numerous shapes. The term "particles" refers to granules, fibers, flakes, spheres, powders, platelets and other shapes and forms known to persons skilled in the art of superabsorbent polymer particles. The SAP particles may be in the shape of fibers, i.e., elongated, acicular superabsorbent polymer particles. The fibers may also be in the form of a long filament that may be woven. SAP may be spherical-like particles. The absorbent core may comprise one or more types of SAP.

[0173] For most absorbent articles, liquid discharges from a wearer occur predominately in the front half of the absorbent article, in particular for a diaper. The front half of the article (as defined by the region between the front edge and a transversal line placed at a distance of half L from the front waist edge **210** or rear waist edge **212** may therefore may comprise most of the absorbent capacity of the core. Thus, at least 60% of the SAP, or at least 65%, 70%, 75%, 80%, or 85% of the SAP may be present in the front half of the absorbent article, while the remaining SAP may be disposed in the rear half of the absorbent article. Alternatively, the SAP distribution may be uniform through the core or may have other suitable distributions.

[0174] The total amount of SAP present in the absorbent core may also vary according to expected user. Diapers for newborns may require less SAP than infant, child, or adult incontinence diapers. The amount of SAP in the core may be about 5 to 60 g or from 5 to 50 g. The average SAP basis weight within the (or "at least one", if several are present) deposition area **8** of the SAP may be at least 50, 100, 200, 300, 400, 500 or more g/m^2. The areas of the channels (e.g., **226**, **226'**, **227**, **227'**) present in the absorbent material deposition area **8** are deduced from the absorbent material deposition area to calculate this average basis weight.

Core Wrap

[0175] The core wrap may be made of a single substrate, material, or nonwoven folded around the absorbent material, or may comprise two (or more) substrates, materials, or nonwovens which are attached to another. Typical attachments are the so-called C-wrap and/or sandwich wrap. In a C-wrap, as illustrated, for example, in FIGS. **29** and **34**, the longitudinal and/or transversal edges of one of the substrates are folded over the other substrate to form flaps. These flaps are then bonded to the external surface of the other substrate, typically by gluing.

[0176] The core wrap may be formed by any materials suitable for receiving and containing the absorbent material. Typical substrate materials used in the production of conventional cores may be used, in particular paper, tissues, films, wovens or nonwovens, or laminates or composites of any of these.

[0177] The substrates may also be air-permeable (in addition to being liquid or fluid permeable). Films useful herein may therefore comprise micro-pores.

[0178] The core wrap may be at least partially sealed along all the sides of the absorbent core so that substantially no absorbent material leaks out of the core. By "substantially no absorbent material" it is meant that less than 5%, less than 2%, less than 1%, or about 0% by weight of absorbent material escape the core wrap. The term "seal" is to be understood in a broad sense. The seal does not need to be continuous along the whole periphery of the core wrap but may be discontinuous along part or the whole of it, such as formed by a series of seal points spaced on a line. A seal may be formed by gluing and/or thermal bonding.

[0179] If the core wrap is formed by two substrates **216**, **216'**, four seals may be used to enclose the absorbent material **260** within the core wrap. For example, a first substrate **216** may be placed on one side of the core (the top side as represented in FIGS. **33-35**) and extend around the core's longitudinal edges to at least partially wrap the opposed bottom side of the core. The second substrate **216'** may be present between the wrapped flaps of the first substrate **216** and the absorbent material **260**. The flaps of the first substrate **216** may be glued to the second substrate **216'** to provide a strong seal. This so called C-wrap construction may provide benefits such as improved resistance to bursting in a wet loaded state compared to a sandwich seal. The front side and rear side of the core wrap may then also be sealed by gluing the first substrate and second substrate to another to provide complete encapsulation of the absorbent material across the whole of the periphery of the core. For the front side and rear side of the core, the first and second substrates may extend and may be joined together in a substantially planar direction, forming for these edges a so-called sandwich construction. In the so-called sandwich construction, the first and second substrates may also extend outwardly on all sides of the core and be sealed flat, or substantially flat, along the whole or parts of the periphery of the core typically by gluing and/or heat/pressure bonding. In an example, neither the first nor the second substrates need to be shaped, so that they may be rectangularly cut for ease of production but other shapes are also within the scope of the present disclosure.

[0180] The core wrap may also be formed by a single substrate which may enclose as in a parcel wrap the absorbent material and be sealed along the front side and rear side of the core and one longitudinal seal.

SAP Deposition Area

[0181] The absorbent material deposition area **208** may be defined by the periphery of the layer formed by the absorbent material **260** within the core wrap, as seen from the top side of the absorbent core. The absorbent material deposition area **208** may have various shapes, in particular, a so-called "dog bone" or "hour-glass" shape, which shows a tapering along its width towards the middle or "crotch" region of the core. In this way, the absorbent material deposition area **8** may have a relatively narrow width in an area of the core intended to be placed in the crotch region of the absorbent article, as illustrated in FIG. **28**. This may provide better wearing comfort. The absorbent material deposition area **8** may also be generally rectangular, for example as shown in FIGS. **31-33**, but other deposition areas, such as a rectangular, "T," "Y," "sand-hour," or "dog-bone" shapes are also within the scope of the present disclosure. The absorbent material may be deposited using any suitable techniques, which may allow relatively precise deposition of SAP at relatively high speed.

Channels

[0182] The absorbent material deposition area **208** may comprise at least one channel **226**, which is at least partially oriented in the longitudinal direction of the article **280** (i.e., has a longitudinal vector component). Other channels may be at least partially oriented in the lateral direction (i.e., has a lateral vector component) or in any other direction. In the following, the plural form "channels" will be used to mean "at least one channel". The channels may have a length L' projected on the longitudinal axis **280** of the article that is at least 10% of the length L of the article. The channels may be formed in various ways. For example, the channels may be formed by zones within the absorbent material deposition area **208** which may be substantially free of, or free of, absorbent material, in particular SAP. In addition or alternatively, the channel(s) may also be formed by continuously or discontinuously bonding the top side of the core wrap to the bottom side of the core wrap through the absorbent material deposition area **208**. The channels may be continuous, but it is also envisioned that the channels may be intermittent. The acquisition-distribution system or layer **250**, or another layer of the article, may also comprise channels, which may or not correspond to the channels of the absorbent core.

[0183] In some instances, the channels may be present at least at the same longitudinal level as the crotch point C or the lateral axis **260** in the absorbent article, as represented in FIG. **28** with the two longitudinally extending channels **226**, **226'**. The channels may also extend from the crotch region **207** or may be present in the front waist region **205** and/or in the rear waist region **206** of the article.

[0184] The absorbent core **228** may also comprise more than two channels, for example, at least 3, at least 4, at least 5, or at least 6 or more. Shorter channels may also be present, for example in the rear waist region **206** or the front waist region **205** of the core as represented by the pair of channels **227**,

227' in FIG. **28** towards the front of the article. The channels may comprise one or more pairs of channels symmetrically arranged, or otherwise arranged relative to the longitudinal axis **280**.

[0185] The channels may be particularly useful in the absorbent core when the absorbent material deposition area is rectangular, as the channels may improve the flexibility of the core to an extent that there is less advantage in using a non-rectangular (shaped) core. Of course channels may also be present in a layer of SAP having a shaped deposition area.

[0186] The channels may be completely oriented longitudinally and parallel to the longitudinal axis or completely oriented transversely and parallel to the lateral axis, but also may have at least portions that are curved.

[0187] In order to reduce the risk of fluid leakages, the longitudinal main channels may not extend up to any of the edges of the absorbent material deposition area **208**, and may therefore be fully encompassed within the absorbent material deposition area **208** of the core. The smallest distance between a channel and the closest edge of the absorbent material deposition area **208** may be at least 5 mm.

[0188] The channels may have a width We along at least part of their length which is at least 2 mm, at least 3 mm, at least 4 mm, up to for example 20 mm, 16 mm, or 12 mm, for example. The width of the channel(s) may be constant through substantially the whole length of the channel or may vary along its length. When the channels are formed by absorbent material-free zone within the absorbent material deposition area **208**, the width of the channels is considered to be the width of the material free zone, disregarding the possible presence of the core wrap within the channels. If the channels are not formed by absorbent material free zones, for example mainly though bonding of the core wrap through the absorbent material zone, the width of the channels is the width of this bonding.

[0189] At least some or all of the channels may be permanent channels, meaning their integrity is at least partially maintained both in the dry state and in the wet state. Permanent channels may be obtained by provision of one or more adhesive materials, for example, the fibrous layer of adhesive material or construction glue that helps adhere a substrate with an absorbent material within the walls of the channel. Permanent channels may also be formed by bonding the upper side and lower side of the core wrap (e.g., the first substrate **216** and the second substrate **216'**) and/or the topsheet **224** to the backsheet **225** together through the channels. Typically, an adhesive may be used to bond both sides of the core wrap or the topsheet and the backsheet through the channels, but it is possible to bond via other known processes, such as pressure bonding, ultrasonic bonding, heat bonding, or combination thereof. The core wrap or the topsheet **224** and the backsheet **225** may be continuously bonded or intermittently bonded along the channels. The channels may advantageously remain or become visible at least through the topsheet and/or backsheet when the absorbent article is fully loaded with a fluid. This may be obtained by making the channels substantially free of SAP, so they will not swell, and sufficiently large so that they will not close when wet. Furthermore, bonding the core wrap to itself or the topsheet to the backsheet through the channels may be advantageous.

Barrier Leg Cuffs

[0190] The absorbent article may comprise a pair of barrier leg cuffs **34**. Each barrier leg cuff may be formed by a piece of material which is bonded to the absorbent article so it may extend upwards from a wearer-facing surface of the absorbent article and provide improved containment of fluids and other body exudates approximately at the junction of the torso and legs of the wearer. The barrier leg cuffs are delimited by a proximal edge **64** joined directly or indirectly to the topsheet **224** and/or the backsheet **225** and a free terminal edge **266**, which is intended to contact and form a seal with the wearer's skin. The barrier leg cuffs **234** extend at least partially between the front waist edge **210** and the rear waist edge **212** of the absorbent article on opposite sides of the longitudinal axis **280** and are at least present at the level of the crotch point (C) or crotch region. The barrier leg cuffs may be joined at the proximal edge **264** with the chassis of the article by a bond **265** which may be made by gluing, fusion bonding, or a combination of other suitable bonding processes. The bond **265** at the proximal edge **264** may be continuous or intermittent. The bond **265** closest to the raised section of the leg cuffs delimits the proximal edge **264** of the standing up section of the leg cuffs.

[0191] The barrier leg cuffs may be integral with the topsheet **224** or the backsheet **225** or may be a separate material joined to the article's chassis. Each barrier leg cuff **234** may comprise one, two or more elastic strings **235** close to the free terminal edge **266** to provide a better seal.

[0192] In addition to the barrier leg cuffs **234**, the article may comprise gasketing cuffs **232**, which are joined to the chassis of the absorbent article, in particular to the topsheet **224** and/or the backsheet **225** and are placed externally relative to the barrier leg cuffs. The gasketing cuffs **232** may provide a better seal around the thighs of the wearer. Each gasketing leg cuff may comprise one or more elastic strings or elastic elements **233** in the chassis of the absorbent article between the topsheet **224** and backsheet **225** in the area of the leg openings. All, or a portion of, the barrier leg cuffs and/or gasketing cuffs may be treated with a lotion or another skin care composition.

Acquisition-Distribution System

[0193] The absorbent articles of the present disclosure may comprise an acquisition-distribution layer or system **250** ("ADS"). One function of the ADS is to quickly acquire one or more of the fluids and distribute them to the absorbent core in an efficient manner. The ADS may comprise one, two or more layers, which may form a unitary layer or may remain as discrete layers which may be attached to each other. In an example, the ADS may comprise two layers: a distribution layer **254** and an acquisition layer **252** disposed between the absorbent core and the topsheet, but the present disclosure is not so limited.

[0194] In one example, the high loft, three-dimensional nonwoven materials of the present disclosure may comprise the topsheet and the acquisition layer as a laminate. A distribution layer may also be provided on the garment-facing side of the topsheet/acquisition layer laminate.

[0195] In another example, the high loft, three dimensional nonwoven materials of the present disclosure may comprise an acquisition layer of an absorbent article and a topsheet of the absorbent article may be generally planar. The topsheet may have an opacity such that the acquisition layer, such as a colored acquisition layer or an acquisition layer with indicia, is visible through the topsheet from the wearer-facing side of the absorbent article.

Carrier Layer

[0196] In an instance where the high loft, three-dimensional nonwoven materials of the present disclosure encompass a topsheet and acquisition layer laminate, the distribution layer may need to be supported by a carrier layer (not illustrated) that may comprise one or more nonwoven materials or other materials. The distribution layer may be applied to or positioned on the carrier layer. As such, the carrier layer may be positioned intermediate the acquisition layer and the distribution layer and be in a facing relationship with the acquisition layer and the distribution layer.

Distribution Layer

[0197] The distribution layer of the ADS may comprise at least 50% by weight of cross-linked cellulose fibers. The cross-linked cellulosic fibers may be crimped, twisted, or curled, or a combination thereof including crimped, twisted, and curled. This type of material is disclosed in U.S. Pat. Publ. No. 2008/0312622 A1 (Hundorf). The cross-linked cellulosic fibers provide higher resilience and therefore higher resistance to the first absorbent layer against the compression in the product packaging or in use conditions, e.g., under wearer weight. This may provide the core with a higher void volume, permeability, and liquid absorption, and hence reduced leakage and improved dryness.

[0198] The distribution layer comprising the cross-linked cellulose fibers of the present disclosure may comprise other fibers, but this layer may advantageously comprise at least 50%, or 60%, or 70%, or 80%, or 90%, or even up to 100%, by weight of the layer, of cross-linked cellulose fibers (including the cross-linking agents).

Acquisition Layer

[0199] If a three-dimensional nonwoven material of the present disclosure is provided as only the topsheet of an absorbent article, the ADS **250** may comprise an acquisition layer **252**. The acquisition layer may be disposed between the distribution layer **254** and the topsheet **224**. In such an instance, the acquisition layer **252** may be or may comprise a nonwoven material, such as a hydrophilic SMS or SMMS material, comprising a spunbonded, a melt-blown and a further spunbonded layer or alternatively a carded staple fiber chemical-bonded nonwoven. The nonwoven material may be latex bonded.

Fastening System

[0200] The absorbent article may comprise a fastening system. The fastening system may be used to provide lateral tensions about the circumference of the absorbent article to hold the absorbent article on the wearer as is typical for taped diapers. This fastening system may not be necessary for training pant articles since the waist region of these articles is already bonded. The fastening system may comprise a fastener such as tape tabs, hook and loop fastening components, interlocking fasteners such as tabs & slots, buckles, buttons, snaps, and/or hermaphroditic fastening components, although any other suitable fastening mechanisms are also within the scope of the present disclosure. A landing zone **244** is normally provided on the garment-facing surface of the front waist region **205** for the fastener to be releasably attached thereto.

Front and Rear Ears

[0201] The absorbent article may comprise front ears **246** and rear ears **240**. The ears may be an integral part of the chassis, such as formed from the topsheet **224** and/or backsheet **226** as side panels. Alternatively, as represented on FIG. **28**, the ears may be separate elements attached by gluing, heat embossing, and/or pressure bonding. The rear ears **240** may be stretchable to facilitate the attachment of the tabs **242** to the landing zone **244** and maintain the taped diapers in place around the wearer's waist. The rear ears **240** may also be elastic or extensible to provide a more comfortable and contouring fit by initially conformably fitting the absorbent article to the wearer and sustaining this fit throughout the time of wear well past when absorbent article has been loaded with fluids or other bodily exudates since the elasticized ears allow the sides of the absorbent article to expand and contract.

Elastic Waist Feature

[0202] The absorbent article **220** may also comprise at least one elastic waist feature (not represented) that helps to provide improved fit and containment. The elastic waist feature is generally intended to elastically expand and contract to dynamically fit the wearer's waist. The elastic waist feature may extend at least longitudinally outwardly from at least one waist edge of the absorbent core **228** and generally forms at least a portion of the end edge of the absorbent article. Disposable diapers may be constructed so as to have two elastic waist features, one positioned in the front waist region and one positioned in the rear waist region.

Sanitary Napkin

[0203] The three-dimensional nonwoven materials of the present disclosure may form a portion of a sanitary napkin, for instance, a portion of, or all of, a topsheet, or portion of, or all of, a topsheet and acquisition layer (or secondary topsheet). In other instances, the three-dimensional nonwoven materials may form a strip or patch placed on the topsheet of the sanitary napkin. An example sanitary napkin **500** is disclosed in FIG. **36**. The sanitary napkin **500** may comprise a liquid permeable topsheet **514**, a liquid impermeable, or substantially liquid impermeable, backsheet **516**, and an absorbent core **508**. The absorbent core **508** may have any or all of the features described herein with respect to the absorbent cores **228** and, in some forms, may have a secondary topsheet (acquisition layer or system) instead of the acquisition-distribution system disclosed above. The sanitary napkin **500** may also comprise wings **520** extending outwardly with respect to a longitudinal axis **580** of the sanitary napkin **500**. The sanitary napkin **500** may also comprise a lateral axis **590**. The wings **520** may be joined to the topsheet **514**, the backsheet **516**, and/or the absorbent core **508**. The sanitary napkin **500** may also comprise a front edge **522**, a rear edge **524** longitudinally opposing the front edge **522**, a first side edge **526**, and a second side edge **528** longitudinally opposing the first side edge **526**. The longitudinal axis **580** may extend from a midpoint of the front edge **522** to a midpoint of the rear edge **524**. The lateral axis **590** may extend from a midpoint of the first side edge **526** to a midpoint of the second side edge **528**. The sanitary napkin **500** may also be provided with additional features commonly found in sanitary napkins as is generally known in the art, such as a secondary topsheet **519**, for example.

Packages

[0204] Absorbent articles comprising airfelt-free cores and the high loft, three-dimensional nonwoven materials of the present disclosure may be placed into packages. The packages may comprise polymeric films and/or other materials. Graphics and/or indicia relating to properties of the absorbent articles may be formed on, printed on, positioned on, and/or placed on outer portions of the packages. Each package may comprise a plurality of absorbent articles. The absorbent articles may be packed under compression so as to reduce the size of the packages, while still providing an adequate amount of absorbent articles per package. By packaging the absorbent articles under compression, caregivers can easily handle and store the packages, while also providing distribution savings to manufacturers owing to the size of the packages.

[0205] As discussed above, one of the unexpected benefits of the absorbent articles of the present disclosure having airfelt-free cores and the nonwoven materials as a topsheet and/or a topsheet and acquisition layer laminate is cost savings to the consumer and the manufacturer owing to reduced stack height. Accordingly, packages of the absorbent articles of the present disclosure may have an In-Bag Stack Height of less than about 100 mm, less than about 95 mm, less than about 90 mm, less than about 85 mm, less than about 85 mm, but greater than about 75 mm, less than about 80 mm, less than about 78 mm, less than about 76 mm, or less than about 74 mm, specifically reciting all 0.1 mm increments within the specified ranges and all ranges formed therein or thereby, according to the In-Bag Stack Height Test described herein. Alternatively, packages of the absorbent articles of the present disclosure may have an In-Bag Stack Height of from about 70 mm to about 100 mm, from about 70 mm to about 95 mm, from about 72 mm to about 85 mm, from about 72 mm to about 80 mm, or from about 74 mm to about 78 mm, specifically reciting all 0.1 mm increments within the specified ranges and all ranges formed therein or thereby, according to the In-Back Stack Height Test described herein.

[0206] FIG. **37** illustrates an example package **1000** comprising a plurality of absorbent articles **1004**. The package **1000** defines an interior space **1002** in which the plurality of absorbent articles **1004** are situated. The plurality of absorbent articles **1004** are arranged in one or more stacks **1006**.

EXAMPLES

Comparative Example 1

[0207] In Comparative Example 1, the material is a composite of two materials glued together using H.B. Fuller of St. Paul, Minn., U.S.A. D3166ZP hot melt adhesive applied in a spiral pattern at a 1 gsm add on level. The composite material is processed through a nip formed by one of The Procter & Gamble Company's SELF rolls and a ring roll as described in U.S. Pat. No. 7,410,683 B2, Curro, et al., at 25 feet/minute (fpm) (7.6 meters per minute) and 0.135" (3.43 mm) DOE. The material layer in contact with the SELF roll is a 20 gsm spunbond nonwoven produced by Fitesa of Simpsonville, S.C., U.S.A. Such a material is described in Fitesa's U.S. patent application Ser. No. 14/206,699 entitled "Extensible Nonwoven Fabric" and is comprised of 2.5 denier fibers comprising a blend of PP and PE fibers. The material layer in contact with the ring roll is a 43 gsm spunbond nonwoven produced by Reicofil of Troisdorf, Germany, comprised of 7 denier co-PET/PET tipped-trilobal bicomponent fibers.

Example 1

Single Layer

[0208] In Example 1, the material is a 50 grams/m^2 (gsm) PE/PP sheath/core bicomponent spunbond nonwoven from Fitesa. It is processed at 25 fpm (7.6 meters per minute) speed at 0.155 inch (3.94 mm) depth of engagement (DOE) through male/female tooling (forming members). The teeth on the male tool have a rounded diamond shape like that shown in FIG. **21**, with vertical sidewalls and a radiused or rounded edge at the transition between the top and the sidewalls of the tooth. The teeth are 0.186 inch (4.72 mm) long and 0.125 inch (3.18 mm) wide with a CD spacing of 0.150 inch (3.81 mm) and an MD spacing of 0.346 inch (8.79 mm). The recesses in the mating female roll also have a rounded diamond shape, similar to that of the male roll, with a clearance between the rolls of 0.032-0.063 inch (0.813-1.6 mm), varying slightly around the perimeter of the recess.

Example 2

Two Layers

[0209] In Example 2, the material is a composite of two materials glued together using the same hot melt adhesive applied in a spiral pattern as described in Comparative Example 1. It is processed through the male/female tooling described in Example 1, at 800 feet per minute (fpm) (24.4 meters per minute) and 0.155 inch (3.94 mm) DOE. The material layer in contact with the male roll is the 20 gsm spunbond nonwoven produced by Fitesa comprised of 2.5 denier fibers with a blend of PP and PE described in Comparative Example 1. The material layer in contact with the female roll is a 60 gsm through-air bonded carded nonwoven produced by Beijing Dayuan Non-Woven Fabric Co, LTD of Beijing, China, comprised of 5 denier PE/PET sheath/core bicomponent fibers.

Example 3

Two Layers

[0210] In Example 3, the material is a composite of two materials glued together using the same hot melt adhesive applied in a spiral pattern as described in Comparative Example 1. It is processed through the male/female tooling described in Example 1, at 800 fpm and 0.155 inch (3.94 mm) DOE. The material layer in contact with the male roll is a 20 gsm spunbond nonwoven produced by Fitesa comprised of 2.5 denier fibers with a blend of PP and PE described in Example 2. The material layer in contact with the female roll is an 86 gsm spunbond nonwoven produced by Reicofil comprised of 7 denier co-PET/PET tipped-trilobal bicomponent fibers.

[0211] The samples are compressed according to the Accelerated Compression Method, with a 7 kPa weight). The pre-compression caliper and the post-compression caliper of the samples are measured following the Accelerated Compression Method. The dimensions of the protrusions and openings are measured using a microscope at 20× magnification. The exterior dimensions of the cap are measured from a perspective view with the protrusions facing up, like that shown in FIG. **5**. The protrusion depth and the interior cap width is measured from the cross-section of the material like that shown in FIG. **11**.

Example	First Layer (Contacts Male Tool)	Second Layer (Contacts Female Tool)	Measured Before or After Compression (7 kPa)	Caliper at 2.1 kPa (mm)	Protrusion Depth (mm)	Base Opening Width (W_0) (mm)	Base Opening Length (mm)	Cap Width-Interior (W_I) (mm)	Cap Width-Exterior (mm)	Cap Length-Exterior (mm)	Ratio of Cap width-Interior to Base Opening Width
Comp. Ex. 1	20 gsm Spunbond PE/PP Blend	43 gsm co-PET/PET Spunbond	Before Compression	1.2	1.1 (Tuft)	0.5	4.7	<0.1* (Tuft)	1.5 (Tuft)	4.6 (Tuft)	—
			After Compression	0.7	0.3	0* (opening was closed)	4.7	0* (opening was closed)	0.7	4.0	—
Ex. 1	50 gsm PE/PP Bico Spunbond	None	Before Compression	0.48	1.3	1.5	3.3	1.7	2.4	4.2	1.1
			After Compression	0.39	0.4	1.7	3.0	2.1	2.9	4.3	1.2
Ex. 2	20 gsm Spunbond PE/PP Blend	60 gsm PET Carded Through-air Bonded	Before Compression	1.6	1.9	1.9	3.5	2.4	3.2	4.5	1.3
			After Compression	0.88	0.5	1.6	3.3	1.8	2.7	4.4	1.1
Ex. 3	20 gsm Spunbond PE/PP Blend	86 gsm co-PET/PET Spunbond	Before Compression	2.0	1.9	1.8	3.8	2.2	3.8	4.8	1.2
			After Compression	1.3	0.7	1.5	3.6	2.5	3.7	5.2	1.7

*Difficult to measure because measurement was so small

Test Methods:

[0212] A. Accelerated Compression Method.

[0213] 1. Cut 10 samples of the specimen to be tested and 11 pieces of a paper towel into a 3 inch×3 inch (7.6 cm×7.6 cm) square.

[0214] 2. Measure the caliper of each of the 10 specimens at 2.1 kPa and a dwell time of 2 seconds using a Thwing-Albert ProGage Thickness Tester or equivalent with a 50-60 millimeter diameter circular foot. Record the pre-compression caliper to the nearest 0.01 mm.

[0215] 3. Alternate the layers of the specimens to be tested with the pieces of paper towel, starting and ending with the paper towels. The choice of paper towel does not matter and is present to prevent "nesting" of the protrusions in the deformed samples. The samples should be oriented so the edges of each of the specimens and each of the paper towels are relatively aligned, and the protrusions in the specimens are all oriented the same direction.

[0216] 4. Place the stack of samples into a 40° C. oven and place a weight on top of the stack. The weight must be larger than the foot of the thickness tester. To simulate high pressures or low in-bag stack heights, apply 35 kPa (e.g. 17.5 kg weight over a 70×70 mm area). To simulate low pressures or high in-bag stack heights, apply 7 kPa (e.g. 3.5 kg weight over a 70×70 mm area).

[0217] 5. Leave the samples in the oven for 15 hours. After the time period has elapsed, remove the weight from the samples and remove the samples from the oven.

[0218] 6. Within 30 minutes of removing the samples from the oven, measure the post-compression caliper as directed in step 2 above, making sure to maintain the same order in which the pre-compression caliper was recorded. Record the post-compression caliper of each of the 10 specimens to the nearest 0.01 mm.

[0219] 7. Let the samples rest at 23±2° C. and at 50±2% relative humidity for 24 hours without any weight on them.

[0220] 8. After 24 hours, measure the post-recovery caliper of each of the 10 specimens as directed in step 2 above, making sure to maintain the same order in which the pre-compression and post-compression calipers were recorded. Record the post-recovery caliper of each of the 10 specimens to the nearest 0.01 mm. Calculate the amount of caliper recovery by subtracting the post-compression caliper from the post-recovery caliper and record to the nearest 0.01 mm.

[0221] 9. If desired, an average of the 10 specimens can be calculated for the pre-compression, post-compression and post-recovery calipers.

[0222] B. Tensile Method

[0223] The MD and CD tensile properties are measured using method WSP 110.4 (05) Option B, with a 50 mm sample width, 60 mm gauge length, and 60 mm/min rate of extension. Note that the gauge length, rate of extension and resultant strain rate are different from that specified within the method.

[0224] C. In-Bag Stack Height Test

The in-bag stack height of a package of absorbent articles is determined as follows:

Equipment

[0225] A thickness tester with a flat, rigid horizontal sliding plate is used. The thickness tester is configured so that the horizontal sliding plate moves freely in a vertical direction with the horizontal sliding plate always maintained in a horizontal orientation directly above a flat, rigid horizontal base plate. The thickness tester includes a suitable device for measuring the gap between the horizontal sliding plate and the horizontal base plate to within ±0.5 mm. The horizontal sliding plate and the horizontal base plate are larger than the surface of the absorbent article package that contacts each plate, i.e. each plate extends past the contact surface of the absorbent article package in all directions. The horizontal sliding plate exerts a downward force of 850±1 gram-force (8.34 N) on the absorbent article package, which may be achieved by placing a suitable weight on the center of the non-package-contacting top surface of the horizontal sliding plate so that the total mass of the sliding plate plus added weight is 850±1 grams.

Test Procedure

[0226] Absorbent article packages are equilibrated at 23±2° C. and 50±5% relative humidity prior to measurement.

[0227] The horizontal sliding plate is raised and an absorbent article package is placed centrally under the horizontal sliding plate in such a way that the absorbent articles within the package are in a horizontal orientation (see FIG. **37**). Any handle or other packaging feature on the surfaces of the package that would contact either of the plates is folded flat against the surface of the package so as to minimize their impact on the measurement. The horizontal sliding plate is lowered slowly until it contacts the top surface of the package and then released. The gap between the horizontal plates is measured to within ±0.5 mm ten seconds after releasing the horizontal sliding plate. Five identical packages (same size packages and same absorbent articles counts) are measured and the arithmetic mean is reported as the package width. The "In-Bag Stack Height"=(package width/absorbent article count per stack)×10 is calculated and reported to within ±0.5 mm.

[0228] The dimensions and values disclosed herein are not to be understood as being strictly limited to the exact numerical values recited. Instead, unless otherwise specified, each such dimension is intended to mean both the recited value and a functionally equivalent range surrounding that value. For example, a dimension disclosed as "90°" is intended to mean "about 90°".

[0229] It should be understood that every maximum numerical limitation given throughout this specification includes every lower numerical limitation, as if such lower numerical limitations were expressly written herein. Every minimum numerical limitation given throughout this specification will include every higher numerical limitation, as if such higher numerical limitations were expressly written herein. Every numerical range given throughout this specification will include every narrower numerical range that falls within such broader numerical range, as if such narrower numerical ranges were all expressly written herein.

[0230] All documents cited in the Detailed Description are, in relevant part, incorporated herein by reference; the citation of any document is not to be construed as an admission that it is prior art with respect to the present disclosure. To the extent that any meaning or definition of a term in this written document conflicts with any meaning or definition of the term in a document incorporated by reference, the meaning or definition assigned to the term in this written document shall govern.

[0231] While particular embodiments of the present disclosure have been illustrated and described, it would be obvious to those skilled in the art that various other changes and modifications can be made without departing from the spirit and scope of the invention. It is therefore intended to cover in the appended claims all such changes and modifications that are within the scope of this invention.

What is claimed is:

1. An absorbent article comprising:

a liquid permeable nonwoven material comprising a first surface and a second surface, the nonwoven material comprising a plurality of fibers, wherein the nonwoven material comprises a generally planar first region and a plurality of discrete integral second regions that comprise deformations forming protrusions extending outward from the first surface of the nonwoven material and openings in the second surface of the nonwoven material, the protrusions being formed from the fibers, wherein at least some of the protrusions comprise a base proximate to the first surface of the nonwoven material, an opposed distal end extending outward in the Z-direction from the base, side walls between the base and the distal end of the protrusion, and a cap comprising at least a portion of the side walls and the distal end of the protrusion, wherein the side walls have interior surfaces, wherein multiple fibers extend from the base of the protrusion to the distal end of the protrusion, and contribute to form a portion of the sides and cap of the protrusion, and wherein the fibers at least substantially surround the sides of the protrusion;

a liquid impermeable material; and

an absorbent core positioned intermediate the liquid permeable nonwoven material and the liquid impermeable material, wherein the absorbent core comprises an absorbent material, and wherein the absorbent material comprises at least 85% superabsorbent polymers by weight of the absorbent material.

2. The absorbent article of claim **1**, wherein the interior surfaces of the side walls define a base opening at the base of the protrusion, wherein the cap has a portion with a maximum interior width, wherein the base opening has a width, and wherein the maximum interior width of the cap of the protrusion is greater than the width of the base opening.

3. The absorbent article of claim **1**, wherein a channel is formed in the absorbent material.

4. The absorbent article of claim **3**, wherein a second channel is formed in the absorbent material.

5. The absorbent article of claim **1**, wherein the absorbent material comprises at least 95% superabsorbent polymers by weight of the absorbent material.

6. The absorbent article of claim **1**, wherein the absorbent material is substantially free of cellulosic, natural or synthetic fibers.

7. The absorbent article of claim **1**, wherein the nonwoven material comprises a single layer.

8. The absorbent article of claim **1**, wherein the nonwoven material comprises an acquisition layer, the absorbent article comprising a topsheet that is generally planar.

9. The absorbent article of claim **8**, wherein the topsheet has an opacity such that the acquisition layer is visible through the topsheet.

10. The absorbent article of claim **1**, wherein the nonwoven material comprises a plurality of layers.

11. The absorbent article of claim **10**, wherein at least two of the plurality of layers are nested within a protrusion.

12. The absorbent article of claim **10**, wherein a first layer is a liquid permeable topsheet, and wherein a second layer is a liquid permeable acquisition material.

13. The absorbent article of claim **12**, comprising a carrier layer and a distribution layer applied to the carrier layer, wherein the carrier layer is in a facing relationship with the liquid permeable acquisition material.

14. The absorbent article of claim **1**, wherein at least some of the protrusions are substantially hollow and form a bulbous shape.

15. A package comprising a plurality of the absorbent articles of claim **1**, wherein the package has an in-bag stack height of less than about 95 mm, according to the In-Back Stack Height Test herein.

16. An absorbent article comprising a multiple layer nonwoven material comprising at least two layers that are joined together, wherein a first layer comprises the nonwoven material of claim **1**, and wherein a second layer comprises a second nonwoven material having a first surface and a second surface, the second nonwoven material comprising a second plurality of fibers, wherein the second nonwoven material comprises a second generally planar first region and a second plurality of discrete integral second regions that comprise deformations forming protrusions extending outward from the first surface of the second nonwoven material, the protrusions being formed from fibers in the second plurality of fibers, wherein the protrusions in the second nonwoven material comprise a base proximate to the first surface of the second nonwoven material, an opposed distal portion, and side walls between the base and the distal portion of the deformation, wherein the deformations form an opening in the second surface of the second nonwoven material, and wherein multiple fibers of the second plurality of fibers are broken along at least a portion of the sides of a protrusion in the second nonwoven.

17. An absorbent article comprising:

a liquid permeable nonwoven material comprising a first surface and a second surface, the nonwoven material comprising a plurality of fibers, wherein the nonwoven material comprises a generally planar first region and a plurality of discrete integral second regions that comprise deformations forming protrusions extending outward from the first surface of the nonwoven material and openings in the second surface of the nonwoven material, the protrusions being formed from the fibers, wherein at least some of the protrusions comprise a base proximate the first surface of the nonwoven material, an opposed distal end extending outward in the Z-direction from the base, side walls between the base and the distal end of the protrusion, and a cap comprising at least a portion of the side walls and the distal end of the protrusion, wherein the side walls have interior surfaces, wherein multiple fibers extend from the base of the protrusion to the distal end of the protrusion, and contribute to form a portion of the sides and cap of a protrusion, wherein the interior surfaces of the side walls define a base opening at the base of the protrusion, wherein the cap has a portion with a maximum interior width, wherein the base opening has a width, and wherein the maximum interior width of the cap of the protrusion is greater than the width of the base opening;

a liquid impermeable material; and

an absorbent core positioned intermediate the nonwoven material and the liquid impermeable material, wherein the absorbent core comprises an absorbent material, wherein the absorbent material comprises at least 85% superabsorbent polymers by weight of the absorbent material, and wherein the absorbent material comprises a channel.

18. The absorbent article of claim **17**, wherein the fibers at least substantially surround the sides of the protrusion.

19. The absorbent article of claim **17**, wherein the absorbent material comprises at least 95% superabsorbent polymers by weight of the absorbent material, wherein the absorbent material is substantially free of cellulosic, natural or synthetic fibers, and wherein the absorbent core comprises an adhesive.

20. The absorbent article of claim **17**, wherein the nonwoven material comprises a single layer.

21. The absorbent article of claim **17**, wherein the nonwoven material comprises a plurality of layers, wherein at least two of the plurality of layers are nested within a protrusion, and wherein the protrusion is substantially hollow and forms a bulbous shape.

22. The absorbent article of claim **21**, wherein a first layer is a liquid permeable topsheet, and wherein a second layer is a liquid permeable acquisition material.

23. The absorbent article of claim **22**, comprising a carrier layer for a distribution material, wherein the carrier layer is in a facing relationship with the liquid permeable acquisition material.

24. A package comprising a plurality of the absorbent articles of claim **17**, wherein the package has an in-bag stack height of less than about 100 mm, but greater than about 70 mm according to the In-Back Stack Height Test herein.

25. A package comprising:

a plurality of absorbent articles, wherein the absorbent articles comprise:

a liquid permeable nonwoven material comprising a first surface and a second surface, the nonwoven material comprising a plurality of fibers, wherein the nonwoven material comprises a generally planar first region and a plurality of discrete integral second regions that comprise deformations forming protrusions extending outward from the first surface of the nonwoven material and openings in the second surface of the nonwoven material, the protrusions being formed from the fibers, wherein at least some of the protrusions comprise a base proximate the first surface of the nonwoven material, an opposed distal end extending outward in the Z-direction from the base, side walls between the base and the distal end of the protrusion, and a cap comprising at least a portion of the side walls and the distal end of the protrusion, wherein the side walls have interior surfaces, wherein multiple fibers extend from the base of the protrusion to the distal end of the protrusion, and contribute to form a portion of the sides and cap of a protrusion, wherein the interior surfaces of the side walls define a base opening at the base of the protrusion, wherein the cap has a portion with a maximum interior width, wherein the base opening has a width, and wherein the maximum interior width of the cap of the protrusion is greater than the width of the base opening;

a liquid impermeable material; and

an absorbent core positioned intermediate the liquid permeable nonwoven material and the liquid impermeable material, wherein the absorbent core comprises an absorbent material, wherein the absorbent material comprises at least 85% superabsorbent polymers by weight of the absorbent material;

wherein the package has an in-bag stack height of less than about 90 mm, according to the In-Back Stack Height Test herein.

26. The package of claim **25**, wherein the liquid permeable nonwoven material comprises a topsheet and an acquisition layer as a laminate.

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