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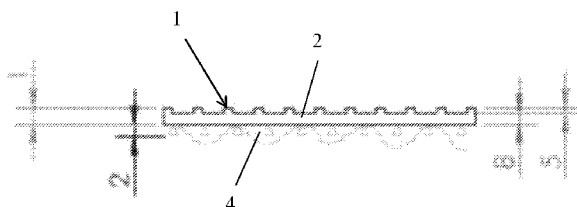


FIG. 1

(57) Abstract: A fabric or belt for a papermaking machine including a first layer that defines a web contacting surface and a second layer that supports the first layer. The first layer is made of extruded polymer and includes a plurality of first elements aligned in a first direction, a plurality of second elements aligned in a second direction and extending over the plurality of first elements, and a plurality of open portions defined by the plurality of first and second elements. The second layer is made of woven fabric. The first layer is bonded to the second layer so that the first layer extends only partially through the second layer and an interface formed between the first and second layers includes bonded and unbonded portions and airflow channels that extend in a plane parallel to the first and second layers.



BELT OR FABRIC INCLUDING POLYMERIC LAYER FOR PAPERMAKING  
MACHINE

RELATED APPLICATIONS

**[0001]** This application is a non-provisional based on and claiming priority to U.S. Provisional Patent Application No. 62/294,158, filed February 11, 2016, and entitled BELT OR FABRIC INCLUDING POLYMERIC LAYER FOR PAPERMAKING MACHINE, the contents of which are incorporated herein by reference in their entirety.

FIELD OF THE INVENTION

**[0002]** This disclosure relates to fabrics or belts for a papermaking machine, and in particular to fabrics or belts that include polymeric layers and that are intended for use on papermaking machines for the production of tissue products.

BACKGROUND

**[0003]** Tissue manufacturers that can deliver the highest quality product at the lowest cost have a competitive advantage in the marketplace. A key component in determining the cost and quality of a tissue product is the manufacturing process utilized to create the product. For tissue products, there are several manufacturing processes available including conventional dry crepe, through air drying (TAD), or “hybrid” technologies such as Valmet’s NTT and QRT processes, Georgia Pacific’s ETAD, and Voith’s ATMOS process. Each has differences as to installed capital cost, raw material utilization, energy cost, production rates, and the ability to generate desired attributes such as softness, strength, and absorbency.

**[0004]** Conventional manufacturing processes include a forming section designed to retain the fiber, chemical, and filler recipe while allowing the water to drain from the web. Many types of forming sections, such as inclined suction breast roll, twin wire C-wrap, twin wire S-wrap, suction forming roll, and Crescent formers, include the use of forming fabrics.

**[0005]** Forming fabrics are woven structures that utilize monofilaments (such as yarns or threads) composed of synthetic polymers (usually polyethylene, polypropylene, or nylon). A forming fabric has two surfaces, the sheet side and the machine or wear side. The wear side is in contact with the elements that support and move the fabric and are thus prone to wear. To increase wear resistance and improve drainage, the wear side of the fabric has larger diameter monofilaments compared to the sheet side. The sheet side has finer yarns to promote fiber and filler retention on the fabric surface.

**[0006]** Different weave patterns are utilized to control other properties such as: fabric stability, life potential, drainage, fiber support, and clean-ability. There are three basic types of forming fabrics: single layer, double layer, and triple layer. A single layer fabric is composed of one yarn system made up of cross direction (CD) yarns (also known as shute yarns) and machine direction (MD) yarns (also known as warp yarns). The main issue for single layer fabrics is a lack of dimensional stability. A double layer forming fabric has one layer of warp yarns and two layers of shute yarns. This multilayer fabric is generally more stable and resistant to stretching. Triple layer fabrics have two separate single layer fabrics bound together by separated yarns called binders. Usually the binder fibers are placed in the cross direction but can also be oriented in the machine direction. Triple layer fabrics have

further increased dimensional stability, wear potential, drainage, and fiber support than single or double layer fabrics.

**[0007]** The manufacturing of forming fabrics includes the following operations: weaving, initial heat setting, seaming, final heat setting, and finishing. The fabric is made in a loom using two interlacing sets of monofilaments (or threads or yarns). The longitudinal or machine direction threads are called warp threads and the transverse or machine direction threads are called shute threads. After weaving, the forming fabric is heated to relieve internal stresses to enhance dimensional stability of the fabric. The next step in manufacturing is seaming. This step converts the flat woven fabric into an endless forming fabric by joining the two MD ends of the fabric. After seaming, a final heat setting is applied to stabilize and relieve the stresses in the seam area. The final step in the manufacturing process is finishing, whereby the fabric is cut to width and sealed.

**[0008]** There are several parameters and tools used to characterize the properties of the forming fabric: mesh and count, caliper, frames, plane difference, open area, air permeability, void volume and distribution, running attitude, fiber support, drainage index, and stacking. None of these parameters can be used individually to precisely predict the performance of a forming fabric on a paper machine, but together the expected performance and sheet properties can be estimated. Examples of forming fabrics designs can be viewed in U.S. Patent Nos. 3,143,150, 4,184,519, 4,909,284, and 5,806,569.

**[0009]** In a conventional dry crepe process, after web formation and drainage (to around 35% solids) in the forming section (assisted by centripetal force around the forming roll and, in some cases, vacuum boxes), a web is transferred

from the forming fabric to a press fabric upon which the web is pressed between a rubber or polyurethane covered suction pressure roll and Yankee dryer. The press fabric is a permeable fabric designed to uptake water from the web as it is pressed in the press section. It is composed of large monofilaments or multi-filamentous yarns, needled with fine synthetic batt fibers to form a smooth surface for even web pressing against the Yankee dryer. Removing water via pressing reduces energy consumption.

**[0010]** In a conventional TAD process, rather than pressing and compacting the web, as is performed in conventional dry crepe, the web undergoes the steps of imprinting and thermal pre-drying. Imprinting is a step in the process where the web is transferred from a forming fabric to a structured fabric (or imprinting fabric) and subsequently pulled into the structured fabric using vacuum (referred to as imprinting or molding). This step imprints the weave pattern (or knuckle pattern) of the structured fabric into the web. This imprinting step increases softness of the web, and affects smoothness and the bulk structure. The manufacturing method of an imprinting fabric is similar to a forming fabric (see U.S. Patent Nos. 3,473,576, 3,573,164, 3,905,863, 3,974,025, and 4,191,609 for examples) except for an additional step if an overlaid polymer is utilized.

**[0011]** Imprinting fabrics with an overlaid polymer are disclosed in U.S. Patent Nos. 5,679,222, 4,514,345, 5,334,289, 4,528,239 and 4,637,859. Specifically, these patents disclose a method of forming a fabric in which a patterned resin is applied over a woven substrate. The patterned resin completely penetrates the woven substrate. The top surface of the patterned resin is flat and openings in the resin have sides that follow a linear path as the sides approach and then penetrate the woven structure.

**[0012]** U.S. Patent Nos. 6,610,173, 6,660,362, 6,998,017, and European Patent No. EP 1 339 915 disclose another technique for applying an overlaid resin to a woven imprinting fabric.

**[0013]** After imprinting, the web is thermally pre-dried by moving hot air through the web while it is conveyed on the structured fabric. Thermal pre-drying can be used to dry the web to over 90% solids before the web is transferred to a steam heated cylinder. The web is then transferred from the structured fabric to the steam heated cylinder through a very low intensity nip (up to 10 times less than a conventional press nip) between a solid pressure roll and the steam heated cylinder. The portions of the web that are pressed between the pressure roll and steam cylinder rest on knuckles of the structured fabric; thereby protecting most of the web from the light compaction that occurs in this nip. The steam cylinder and an optional air cap system, for impinging hot air, then dry the sheet to up to 99% solids during the drying stage before creping occurs. The creping step of the process again only affects the knuckle sections of the web that are in contact with the steam cylinder surface. Due to only the knuckles of the web being creped, along with the dominant surface topography being generated by the structured fabric, and the higher thickness of the TAD web, the creping process has much smaller effect on overall softness as compared to conventional dry crepe. After creping, the web is optionally calendered and reeled into a parent roll and ready for the converting process. Some TAD machines utilize fabrics (similar to dryer fabrics) to support the sheet from the crepe blade to the reel drum to aid in sheet stability and productivity. Patents which describe creped through air dried products include U.S. Patent Nos. 3,994,771, 4,102,737, 4,529,480, and 5,510,002.

**[0014]** The TAD process generally has higher capital costs as compared to a conventional tissue machine due to the amount of air handling equipment needed for the TAD section. Also, the TAD process has a higher energy consumption rate due to the need to burn natural gas or other fuels for thermal pre-drying. However, the bulk softness and absorbency of a paper product made from the TAD process is superior to conventional paper due to the superior bulk generation via structured fabrics, which creates a low density, high void volume web that retains its bulk when wetted. The surface smoothness of a TAD web can approach that of a conventional tissue web. The productivity of a TAD machine is less than that of a conventional tissue machine due to the complexity of the process and the difficulty of providing a robust and stable coating package on the Yankee dryer needed for transfer and creping of a delicate a pre-dried web.

**[0015]** UCTAD (un-creped through air drying) is a variation of the TAD process in which the sheet is not creped, but rather dried up to 99% solids using thermal drying, blown off the structured fabric (using air), and then optionally calendered and reeled. U.S. Patent No. 5,607,551 describes an uncreped through air dried product.

**[0016]** A process/method and paper machine system for producing tissue has been developed by the Voith company and is marketed under the name ATMOS. The process/method and paper machine system has several variations, but all involve the use of a structured fabric in conjunction with a belt press. The major steps of the ATMOS process and its variations are stock preparation, forming, imprinting, pressing (using a belt press), creping, calendering (optional), and reeling the web.

**[0017]** The stock preparation step of the ATMOS process is the same as that of a conventional or TAD machine. The forming process can utilize a twin wire former (as described in U.S. Patent No. 7,744,726), a Crescent Former with a suction Forming Roll (as described in U.S. Patent No. 6,821,391), or a Crescent Former (as described in U.S. Patent No. 7,387,706). The former is provided with a slurry from the headbox to a nip formed by a structured fabric (inner position/in contact with the forming roll) and forming fabric (outer position). The fibers from the slurry are predominately collected in the valleys (or pockets, pillows) of the structured fabric and the web is dewatered through the forming fabric. This method for forming the web results in a bulk structure and surface topography as described in U.S. Patent No. 7,387,706 (Figs. 1-11). After the forming roll, the structured and forming fabrics separate, with the web remaining in contact with the structured fabric.

**[0018]** The web is now transported on the structured fabric to a belt press. The belt press can have multiple configurations. The press dewateres the web while protecting the areas of the sheet within the structured fabric valleys from compaction. Moisture is pressed out of the web, through the dewatering fabric, and into the vacuum roll. The press belt is permeable and allows for air to pass through the belt, web, and dewatering fabric, and into the vacuum roll, thereby enhancing the moisture removal. Since both the belt and dewatering fabric are permeable, a hot air hood can be placed inside of the belt press to further enhance moisture removal. Alternately, the belt press can have a pressing device which includes several press shoes, with individual actuators to control cross direction moisture profile, or a press roll. A common arrangement of the belt press has the web pressed against a permeable dewatering fabric across a vacuum roll by a permeable extended nip belt press. Inside the belt press is a hot air hood that includes a steam shower to enhance moisture removal. The hot air hood

apparatus over the belt press can be made more energy efficient by reusing a portion of heated exhaust air from the Yankee air cap or recirculating a portion of the exhaust air from the hot air apparatus itself.

**[0019]** After the belt press, a second press is used to nip the web between the structured fabric and dewatering felt by one hard and one soft roll. The press roll under the dewatering fabric can be supplied with vacuum to further assist water removal. This belt press arrangement is described in U.S. Patent Nos. 8,382,956 and 8,580,083, with Fig. 1 showing the arrangement. Rather than sending the web through a second press after the belt press, the web can travel through a boost dryer, a high pressure through air dryer, a two pass high pressure through air dryer or a vacuum box with hot air supply hood. U.S. Patent Nos. 7,510,631, 7,686,923, 7,931,781, 8,075,739, and 8,092,652 further describe methods and systems for using a belt press and structured fabric to make tissue products each having variations in fabric designs, nip pressures, dwell times, etc., and are mentioned here for reference. A wire turning roll can be also be utilized with vacuum before the sheet is transferred to a steam heated cylinder via a pressure roll nip.

**[0020]** The sheet is now transferred to a steam heated cylinder via a press element. The press element can be a through drilled (bored) pressure roll, a through drilled (bored) and blind drilled (blind bored) pressure roll, or a shoe press. After the web leaves this press element and before it contacts the steam heated cylinder, the % solids are in the range of 40-50%. The steam heated cylinder is coated with chemistry to aid in sticking the sheet to the cylinder at the press element nip and also to aid in removal of the sheet at the doctor blade. The sheet is dried to up to 99% solids by the steam heated cylinder and an installed hot air

impingement hood over the cylinder. This drying process, the coating of the cylinder with chemistry, and the removal of the web with doctoring is explained in U.S. Patent Nos. 7,582,187 and 7,905,989. The doctoring of the sheet off the Yankee, i.e., creping, is similar to that of TAD with only the knuckle sections of the web being creped. Thus, the dominant surface topography is generated by the structured fabric, with the creping process having a much smaller effect on overall softness as compared to conventional dry crepe. The web is now calendered (optional), slit, reeled and ready for the converting process.

**[0021]** The ATMOS process has capital costs between that of a conventional tissue machine and a TAD machine. It uses more fabrics and a more complex drying system compared to a conventional machine, but uses less equipment than a TAD machine. The energy costs are also between that of a conventional and a TAD machine due to the energy efficient hot air hood and belt press. The productivity of the ATMOS machine has been limited due to the inability of the novel belt press and hood to fully dewater the web and poor web transfer to the Yankee dryer, likely driven by poor supported coating packages, the inability of the process to utilize structured fabric release chemistry, and the inability to utilize overlaid fabrics to increase web contact area to the dryer. Poor adhesion of the web to the Yankee dryer has resulted in poor creping and stretch development which contributes to sheet handling issues in the reel section. The result is that the output of an ATMOS machine is currently below that of conventional and TAD machines. The bulk softness and absorbency is superior to conventional, but lower than a TAD web since some compaction of the sheet occurs within the belt press, especially areas of the web not protected within the pockets of the fabric. Also, bulk is limited since there is no speed differential to help drive the web into the structured fabric as exists on a TAD machine. The surface smoothness of an ATMOS

web is between that of a TAD web and a conventional web primarily due to the current limitation on use of overlaid structured fabrics.

**[0022]** The ATMOS manufacturing technique is often described as a hybrid technology because it utilizes a structured fabric like the TAD process, but also utilizes energy efficient means to dewater the sheet like the conventional dry crepe process. Other manufacturing techniques which employ the use of a structured fabric along with an energy efficient dewatering process are the ETAD process and NTT process. The ETAD process and products are described in U.S. Patent Nos. 7,339,378, 7,442,278, and 7,494,563. The NTT process and products are described in WO 2009/061079 A1, US Patent Application Publication No. 2011/0180223 A1, and US Patent Application Publication No. 2010/0065234 A1. The QRT process is described in US Patent Application Publication No. 2008/0156450 A1 and U.S. Patent No. 7,811,418. A structuring belt manufacturing process used for the NTT, QRT, and ETAD imprinting process is described in U.S. Patent No. 8,980,062 and U.S. Patent Application Publication No. US 2010/0236034.

**[0023]** The NTT process involves spirally winding strips of polymeric material, such as industrial strapping or ribbon material, and adjoining the sides of the strips of material using ultrasonic, infrared, or laser welding techniques to produce an endless belt. Optionally, a filler or gap material can be placed between the strips of material and melted using the aforementioned welding techniques to join the strips of materials. The strips of polymeric material are produced by an extrusion process from any polymeric resin such as polyester, polyamide, polyurethane, polypropylene, or polyether ether ketone resins. The strip material can also be reinforced by incorporating monofilaments of polymeric material into the strips

during the extrusion process or by laminating a layer of woven polymer monofilaments to the non-sheet contacting surface of a finished endless belt composed of welded strip material. The endless belt can have a textured surface produced using processes such as sanding, graving, embossing, or etching. The belt can be impermeable to air and water, or made permeable by processes such as punching, drilling, or laser drilling. Examples of structuring belts used in the NTT process can be viewed in International Publication Number WO 2009/067079 A1 and US Patent Application Publication No. 2010/0065234 A1.

**[0024]** As shown in the aforementioned discussion of tissue papermaking technologies, the fabrics or belts utilized are critical in the development of the tissue web structure and topography which, in turn, are instrumental in determining the quality characteristics of the web such as softness (bulk softness and surfaces smoothness) and absorbency. The manufacturing process for making these fabrics has been limited to weaving a fabric (primarily forming fabrics and structured fabrics) or a base structure and needling synthetic fibers (press fabrics) or overlaying a polymeric resin (overlaid structured fabrics) to the fabric/base structure, or welding strips of polymeric material together to form an endless belt.

**[0025]** Conventional overlaid structures require application of an uncured polymer resin over a woven substrate where the resin completely penetrates through the thickness of the woven structure. Certain areas of the resin are cured and other areas are uncured and washed away from the woven structure. This results is a fabric where airflow through the fabric is only possible in the Z-direction. Thus, in order for the web to dry efficiently, only highly

permeable fabrics can be utilized, meaning the amount of overlaid resin applied needs to be limited. If a fabric of low permeability is produced in this manner, then drying efficiency is significantly reduced, resulting in poor energy efficiency and/or low production rates as the web must be transported slowly across the TAD drums or ATMOS drum for sufficient drying. Similarly, a welded polymer structuring layer is extremely planar and provides an even surface when laminating to a woven support layer (FIG. 9), which results in little if any air channels in the X-Y plane.

#### SUMMMARY OF THE INVENTION

**[0026]** An object of this invention is to provide an alternate process for manufacturing structured fabrics. It is also the purpose of this invention to provide a less complex, lower cost, higher production technique to produce these fabrics. This process can be used to produce structuring fabrics and forming fabrics.

**[0027]** In an exemplary embodiment, the inventive process uses extruded polymeric netting material to create the fabric. The extruded polymer netting is optionally laminated to additional layers of extruded polymer netting, woven polymer monofilament, or woven monofilaments or multi-filamentous yarns needled with fine synthetic batt fibers.

**[0028]** Another object of this invention is to provide a press section of a paper machine that can utilize the inventive structuring fabric to produce high quality, high bulk tissue paper. This press section combines the low capital cost, high production rate, low energy consumption advantages of the NTT manufacturing process, but improves the quality to levels that can be achieved with TAD technology.

**[0029]** The inventive process avoids the tedious and expensive conventional prior art process used to produce woven fabrics using a loom or the time, cost, and precision needed to produce welded fabrics using woven strips of polymeric material that need to be engraved, embossed, or laser drilled. The fabrics produced using the inventive process can be utilized as forming fabrics on any papermaking machine or as a structuring belt on tissue machines utilizing the TAD (creped or uncreped), NTT, QRT, ATMOS, ETAD or other hybrid processes.

**[0030]** In an exemplary embodiment, a low porosity structuring belt of the inventive design is used on a TAD machine where the air flows through the TAD drum from a hot air impingement hood or air cap. High air flow through the inventive structuring belt is not required to effectively dry the imprinted sheet, leading to lower heat demand and fuel consumption.

**[0031]** In an exemplary embodiment, a press section of a tissue machine can be used in conjunction with structured fabrics of this invention to produce high quality tissue with low capital and operational costs. This combination of high quality tissue produced at high productivity rates using low capital and operational costs is not currently available using conventional technologies.

**[0032]** According to an exemplary embodiment of the present invention, a fabric or belt for a papermaking machine comprises: a first layer that defines a web contacting surface, the first layer being made of extruded polymer and comprising: a plurality of first elements aligned in a first direction; a plurality of second elements aligned in a second direction and extending over the plurality of first elements; and a plurality of open portions defined by the

plurality of first and second elements; and a second layer made of woven fabric that supports the first layer, wherein the first layer is bonded to the second layer so that the first layer extends only partially through the second layer and an interface formed between the first and second layers comprises airflow channels that extend in a plane parallel to the first and second layers.

**[0033]** According to at least one exemplary embodiment, the interface between the first and second layers comprises bonded and non-bonded portions.

**[0034]** According to at least one exemplary embodiment, the first layer extends into the second layer by an amount of 30  $\mu\text{m}$  or less.

**[0035]** According to at least one exemplary embodiment, the first layer has a thickness of 0.25 mm to 1.7 mm.

**[0036]** According to at least one exemplary embodiment, the first layer has a thickness of 0.4 mm to 0.75 mm.

**[0037]** According to at least one exemplary embodiment, the first layer has a thickness of 0.5 mm to 0.6 mm.

**[0038]** According to at least one exemplary embodiment, the plurality of open portions repeat across the first layer in both machine and cross directions at regular intervals.

**[0039]** According to at least one exemplary embodiment, the plurality of open portions are rectangular-shaped open portions.

- [0040] According to at least one exemplary embodiment, the rectangular-shaped open portions are defined by sides with a length of 0.25 mm to 1.0 mm.
- [0041] According to at least one exemplary embodiment, the rectangular-shaped open portions are defined by sides with a length of 0.4 mm to 0.75 mm.
- [0042] According to at least one exemplary embodiment, the rectangular-shaped open portions are defined by sides with a length of 0.5 mm to 0.7 mm.
- [0043] According to at least one exemplary embodiment, the plurality of open portions are square-shaped open portions.
- [0044] According to at least one exemplary embodiment, the plurality of open portions are circular-shaped open portions.
- [0045] According to at least one exemplary embodiment, the diameter of the circular-shaped open portions is 0.25 mm to 1.0 mm.
- [0046] According to at least one exemplary embodiment, the diameter of the circular-shaped open portions is 0.4 mm to 0.75 mm.
- [0047] According to at least one exemplary embodiment, the diameter of the circular-shaped open portions is 0.1 mm to 0.7 mm.
- [0048] According to at least one exemplary embodiment, the plurality of second elements extend above the plurality of first elements by an amount of 0.05 mm to 0.40 mm.

- [0049] According to at least one exemplary embodiment, the plurality of second elements extend above the plurality of first elements by an amount of 0.1 mm to 0.3 mm.
- [0050] According to at least one exemplary embodiment, the plurality of second elements extend above the plurality of first elements by an amount of 0.1 mm to 0.2 mm.
- [0051] According to at least one exemplary embodiment, the plurality of second elements have a width of 0.1 mm to 0.5 mm.
- [0052] According to at least one exemplary embodiment, the plurality of second elements have a width of 0.2 mm to 0.4 mm.
- [0053] According to at least one exemplary embodiment, the plurality of second elements have a width of 0.25 mm to 0.3 mm.
- [0054] According to at least one exemplary embodiment, the plurality of first elements have a thickness of 0.15 mm to 0.75 mm.
- [0055] According to at least one exemplary embodiment, the plurality of first elements have a thickness of 0.3 mm to 0.6 mm.
- [0056] According to at least one exemplary embodiment, the plurality of first elements have a thickness of 0.4 mm to 0.6 mm.
- [0057] According to at least one exemplary embodiment, the plurality of first elements have a width of 0.25 mm to 1.0 mm.

- [0058] According to at least one exemplary embodiment, the plurality of first elements have a width of 0.3 mm to 0.5 mm.
- [0059] According to at least one exemplary embodiment, the plurality of first elements have a width of 0.4 mm to 0.5 mm.
- [0060] According to at least one exemplary embodiment, the first layer is made of polymer or copolymer.
- [0061] According to at least one exemplary embodiment, the first layer is made of an extruded netting tube.
- [0062] According to at least one exemplary embodiment, the extruded netting tube is stretched to orient the polymer or copolymer.
- [0063] According to at least one exemplary embodiment, the first layer is made of a perforated sheet.
- [0064] According to at least one exemplary embodiment, the perforated sheet is stretched to orient the polymer or copolymer.
- [0065] According to at least one exemplary embodiment, the perforated sheet is seamed using thermal, laser, infrared or ultraviolet seaming.
- [0066] According to at least one exemplary embodiment, the second layer comprises woven polymeric monofilaments.

- [0067] According to at least one exemplary embodiment, the second layer comprises woven monofilaments or multi-filamentous yarns needled with fine synthetic batt fibers.
- [0068] According to at least one exemplary embodiment, the second layer has a 5 shed weave with a non-numerical warp pick sequence.
- [0069] According to at least one exemplary embodiment, the second layer has a mesh of 10 to 30 frames/cm.
- [0070] According to at least one exemplary embodiment, the second layer has a mesh of 15 to 25 frames/cm.
- [0071] According to at least one exemplary embodiment, the second layer has a mesh of 17 to 22 frames/cm.
- [0072] According to at least one exemplary embodiment, the second layer has a count of 5 to 30 frames/cm.
- [0073] According to at least one exemplary embodiment, the second layer has a count of 10 to 20 frames/cm.
- [0074] According to at least one exemplary embodiment, the second layer has a count of 15 to 20 frames/cm.
- [0075] According to at least one exemplary embodiment, the second layer has a caliper of 0.5 mm to 1.5 mm.

- [0076] According to at least one exemplary embodiment, the second layer has a caliper of 0.5 mm to 1.0 mm.
- [0077] According to at least one exemplary embodiment, the second layer has a caliper of 0.5 mm to 0.75 mm.
- [0078] According to at least one exemplary embodiment, the second layer is bonded to the first layer by thermal, ultrasonic, ultraviolet or infrared welding.
- [0079] According to at least one exemplary embodiment, the second layer is bonded to the first layer with a 20% to 50% contact area.
- [0080] According to at least one exemplary embodiment, the second layer is bonded to the first layer with a 20% to 30% contact area.
- [0081] According to at least one exemplary embodiment, the second layer is bonded to the first layer with a 25% to 30% contact area.
- [0082] According to at least one exemplary embodiment, the fabric or belt has an air permeability of 20 cfm to 300 cfm.
- [0083] According to at least one exemplary embodiment, the fabric or belt has an air permeability of 100 cfm to 250 cfm.
- [0084] According to at least one exemplary embodiment, the fabric or belt has an air permeability of 200 cfm to 250 cfm.

- [0085] According to at least one exemplary embodiment, the fabric or belt is a structuring fabric configured for use on a papermaking machine.
- [0086] According to at least one exemplary embodiment, the papermaking machine is a Through Air Dried, ATMOS, NTT, QRT or ETAD tissue making machine.
- [0087] According to at least one exemplary embodiment, the fabric or belt is a forming fabric configured for use on a papermaking machine.
- [0088] According to at least one exemplary embodiment, the plurality of second elements extend below the plurality of first elements.
- [0089] According to at least one exemplary embodiment, the plurality of second elements extend below the plurality of first elements by less than 0.40 mm.
- [0090] According to at least one exemplary embodiment, the plurality of second elements extend below the plurality of first elements by 0.1 mm to 0.3 mm.
- [0091] According to at least one exemplary embodiment, the plurality of second elements extend below the plurality of first elements by 0.1 mm to 0.2 mm.
- [0092] According to at least one exemplary embodiment, the first direction is substantially parallel to a machine cross direction.
- [0093] According to at least one exemplary embodiment, the second direction is substantially parallel to a machine direction.

[0094] According to at least one exemplary embodiment, the first direction is substantially parallel to a machine direction.

[0095] According to at least one exemplary embodiment, the second direction is substantially parallel to a machine cross direction.

[0096] A fabric or belt for a papermaking machine according to an exemplary embodiment of the present invention comprises: a first layer that defines a web contacting surface, the first layer being made of extruded polymer and comprising: a plurality of first elements aligned in a first direction; a plurality of second elements aligned in a second direction and extending over the plurality of first elements; and a plurality of open portions defined by the plurality of first and second elements; and a second layer made of woven fabric that supports the first layer, wherein the first layer is bonded to the second layer so as to form an interface between the first and second layers that comprises bonded and unbonded portions and airflow channels that extend in a plane parallel to the first and second layers.

[0097] According to at least one exemplary embodiment, the first layer extends only partially through the second layer.

[0098] According to at least one exemplary embodiment, the first layer extends into the second layer by an amount of 30  $\mu\text{m}$  or less.

[0099] A fabric or belt for a papermaking machine according to an exemplary embodiment of the present invention comprises: a first layer that defines a web contacting surface, the first layer comprising a plurality of grooves aligned substantially in the machine direction; and a second layer made of woven fabric that supports the first layer, wherein the first layer

is bonded to the second layer so as to form an interface between the first and second layers that comprises bonded and unbonded portions and airflow channels that extend in a plane parallel to the first and second layers.

**[00100]** According to at least one exemplary embodiment, the plurality of grooves are angled 0.1% to 45% relative to the machine direction.

**[00101]** According to at least one exemplary embodiment, the plurality of grooves are angled 0.1% to 5% relative to the machine direction.

**[00102]** According to at least one exemplary embodiment, the plurality of grooves are angled 2% to 3% relative to the machine direction.

**[00103]** According to at least one exemplary embodiment, the plurality of grooves have a depth of 0.25 mm to 1.0mm.

**[00104]** According to at least one exemplary embodiment, the plurality of grooves have a depth of 0.4 mm to 0.75mm.

**[00105]** According to at least one exemplary embodiment, the plurality of grooves have a depth of 0.4 mm to 0.6mm.

**[00106]** According to at least one exemplary embodiment, the plurality of grooves have a square, semicircular or tapered cross section.

**[00107]** According to at least one exemplary embodiment, the plurality of grooves are spaced 0.1 mm to 1.5 mm apart from each other.

**[00108]** According to at least one exemplary embodiment, the plurality of grooves are spaced 0.2 mm to 0.5 mm apart from each other.

**[00109]** According to at least one exemplary embodiment, the plurality of grooves are spaced 0.2 mm to 0.3 mm apart from each other.

**[00110]** According to at least one exemplary embodiment, the plurality of grooves are formed by laser drilling.

**[00111]** According to at least one exemplary embodiment, the fabric or belt is subjected to punching, drilling or laser drilling to achieve an air permeability of 20 cfm to 200 cfm.

**[00112]** According to at least one exemplary embodiment, the fabric or belt has an air permeability of 20 cfm to 100 cfm.

**[00113]** According to at least one exemplary embodiment, the fabric or belt has an air permeability of 10 cfm to 50 cfm.

**[00114]** A fabric or belt for a papermaking machine according to an exemplary embodiment of the present invention comprises: first layer that defines a web contacting surface, the first layer comprising: a plurality of first elements aligned in a cross direction, the plurality of first elements having a thickness of 0.3 mm to 0.6 mm and a width of 0.4 mm to 0.5 mm; a plurality of second elements aligned in a machine direction and extending over the plurality of first elements by an amount of 0.1 mm to 0.2 mm and having a width of 0.25 mm to 0.3 mm; and a plurality of open portions defined by the plurality of first and second elements and that repeat across the at least one nonwoven layer in both the machine and cross directions at regular intervals, the plurality of open portions being square shaped and

defined by sides with a length of 0.5 mm to 0.7 mm; and a woven fabric layer that supports the at least one layer, wherein the fabric or belt has an air permeability of 20 cfm to 300 cfm.

**[00115]** A fabric or belt for a papermaking machine according to an exemplary embodiment of the present invention comprises: at least one layer that defines a web contacting surface, the at least one layer comprising: a plurality of first elements aligned in a cross direction, the plurality of first elements having a thickness of 0.3 mm to 0.6 mm and a width of 0.4 mm to 0.5 mm; a plurality of second elements aligned in a machine direction and extending over the plurality of first elements by an amount of 0.1 mm to 0.2 mm and having a width of 0.25 mm to 0.3 mm; and a plurality of open portions defined by the plurality of first and second elements and that repeat across the at least one layer in both the machine and cross directions at regular intervals, the plurality of open portions being circular shaped with a diameter of 0.5 mm to 0.7 mm; and a woven fabric layer that supports the at least one layer, wherein the fabric or belt has an air permeability of 20 cfm to 300 cfm.

**[00116]** A method of forming a tissue product according to an exemplary embodiment of the present invention comprises: depositing a nascent paper web onto a forming fabric of a papermaking machine so as to form a paper web; at least partially dewatering the paper web through a structuring fabric of a press section of the papermaking machine, wherein the structuring fabric comprises: a first layer that defines a web contacting surface, the first layer being made of extruded polymer and comprising: a plurality of first elements aligned in a first direction; a plurality of second elements aligned in a second direction and

extending over the plurality of first elements; and a plurality of open portions defined by the plurality of first and second elements; and a second layer made of woven fabric that supports the first layer, wherein the first layer is bonded to the second layer so that the first layer extends only partially through the second layer and an interface formed between the first and second layers comprise airflow channels that extend in a plane parallel to the first and second layers; and drying the at least partially dewatered paper web at a drying section of the papermaking machine.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[00117]** The features and advantages of exemplary embodiments of the present invention will be more fully understood with reference to the following, detailed description when taken in conjunction with the accompanying figures, wherein:

**[00118]** FIG. 1 is a cross-sectional view of a fabric or belt according to an exemplary embodiment of the present invention;

**[00119]** FIG. 2 is a top planar view of the fabric or belt of FIG. 1;

**[00120]** FIG. 3 is a block diagram of a press section according to an exemplary embodiment of the present invention;

**[00121]** FIG. 4 is a cross-sectional view of a fabric or belt according to an exemplary embodiment of the present invention;

**[00122]** FIG. 5 is a planar view of the fabric of belt of FIG. 4;

[00123] FIG. 6 is a photo showing a magnified image of a fabric or belt according to an exemplary embodiment of the present invention;

[00124] FIG. 7 is a photo of a fabric or belt according to an exemplary embodiment of the present invention;

[00125] FIG. 8 is a photo showing air channels formed in the fabric or belt according to an exemplary embodiment of the present invention;

[00126] FIG. 9 is a photo of a welded polymer structuring layer according to the conventional art;

[00127] FIG. 10 is a cross-sectional view of a fabric or belt according to an exemplary embodiment of the present invention;

[00128] FIG. 11 is a cross-sectional view of a fabric or belt according to an exemplary embodiment of the present invention; and

[00129] FIG. 12 is a sectional perspective view of a fabric or belt according to an exemplary embodiment of the present invention.

#### DETAILED DESCRIPTION

[00130] Current methods for manufacturing papermaking fabrics are very time consuming and expensive, requiring weaving together polymer monofilaments using a loom and optionally binding a polymer overlay, or binding strips of polymeric ribbon material together using ultrasonic, infrared, or ultraviolet welding techniques. According to an exemplary embodiment of the present invention, a layer of extruded polymeric material is formed

separately from a woven fabric layer, and the layer of polymeric material is attached to the woven fabric layer to form the fabric or belt structure. The layer of polymeric material includes elevated elements that extend substantially in the machine direction or cross direction.

**[00131]** In an exemplary embodiment, the layer of polymeric material is extruded polymer netting. Extruded netting tubes were first manufactured around 1956 in accordance with the process described in U.S. Patent No. 2,919,467. The process creates a polymer net which in general has diamond shaped openings extending along the length of the tube. Since this process was pioneered, it has grown tremendously, with extruded square netting tubes being described in U.S. Patent Nos. 3,252,181, 3,384,692, and 4,038,008. Nets can also be extruded in flat sheets as described in U.S. Patent No. 3,666,609 which are then perforated or embossed to a selected geometric configuration. Heating and stretching the netting is conducted to enlarge the openings in the net structure and orient the polymers to increase strength. Tube netting can be stretched over a cylindrical mandrel while both tube and flat sheet netting can be stretched in the longitudinal and transverse directions using several techniques. U.S. Patent No. 4,190,692 describes a process of stretching the netting to orient the polymer and increase strength.

**[00132]** Today, various types of polymers can be extruded to provide the optimal level of strength, stretch, heat resistance, abrasion resistance and a variety of other physical properties. Polymers can be coextruded in layers allowing for an adhesive agent to be incorporated into the outer shell of the netting to facilitate thermal lamination of multiple layers of netting.

**[00133]** According to an exemplary embodiment of the present invention, extruded netted tubes are used in fabrics in the papermaking process to lower the material cost, improve productivity, and improve product quality. The positions where this type of fabric can have the most impact are as the forming fabrics of any paper machine or as the structuring fabric on Through Air Dried (creped or uncreped), ATMOS, NTT, QRT or ETAD tissue paper making machines.

**[00134]** The extruded netted tubes have openings that are square, diamond, circular, or any geometric shape that can be produced with the dye equipment used in the extrusion process. The netted tubes are composed of any combination of polymers necessary to develop the stretch, strength, heat resistance, and abrasion resistance necessary for the application. Additionally, coextrusion is preferred with an adhesive agent incorporated into the outer shell of the netting. The adhesive agent facilitates thermal lamination of multiple layers of netting, thermal lamination of netting to woven monofilaments, or thermal lamination of netting to woven monofilaments or multi-filamentous yarns needled with fine synthetic batt fibers. The netting is preferably stretched across a cylindrical mandrel to orient the polymers for increased strength and control over the size of the openings in the netting.

**[00135]** Netting that has been extruded in flat sheets and perforated with openings in the preferred geometric shapes can also be utilized. These nettings are preferably coextruded with an adhesive agent incorporated into the outer shell of the netting to facilitate thermal lamination of multiple layers of netting, thermal lamination of netting to woven monofilaments, or thermal lamination of netting to woven monofilaments or multi-filamentous yarns needled with fine synthetic batt fibers. The netting is preferable heated

and stretched in the longitudinal and transverse direction to control the size of the opening and increase strength of the net. When flat netting is utilized, seaming is used to produce an endless tube. Seaming techniques using a laser or ultrasonic welding are preferred.

**[00136]** FIG. 1 is a cross-sectional view and FIG. 2 is a top planar view of a structuring belt or fabric, generally designated by reference number 1, according to an exemplary embodiment of the present invention. The belt or fabric 1 is multilayered and includes a layer 2 that forms the side of the belt or fabric carrying the paper web, and a woven fabric layer 4 forming the non-paper web contacting side of the belt or fabric. The layer 2 is comprised of netted tube of coextruded polymer with a thickness (1) of 0.25 mm to 1.7 mm, with openings being regularly recurrent and distributed in the longitudinal (MD) and cross direction (CD) of the layer 2 or substantially parallel (plus or minus 10 degrees) thereto. The openings are square with a width (8) and length (3) between 0.25 to 1.0 mm or circular with a diameter between 0.25 to 1.0 mm. The MD aligned elements of the netting of the layer 2 extend (5) 0.05 to 0.40mm above the top plane of the CD aligned elements of the netting. The CD aligned elements of the netting of the structuring layer 2 have a thickness (8) of 0.34 mm. The widths (6) of the MD aligned elements of the netting of the layer 2 are between 0.1 to 0.5mm. The widths (7) of the CD aligned elements are between 0.25 to 1.0 mm, as well. The two layers 2, 4 are laminated together using heat to melt the adhesive in the polymer of the layer 2. Ultrasonic, infrared, and laser welding can also be utilized to laminate the layers 2, 4. As discussed in further detail below, the lamination of the two layers results in the layer 2 extending only partially through the thickness of the woven fabric layer 4, with some portions of the layer 2 remaining unbonded to the woven fabric layer 4.

**[00137]** Optionally, as shown in FIG. 10, the MD aligned elements of the netting of the layer 1 can extend (9) up to 0.40mm below the bottom plane of the CD aligned portion of the netting to further aid in air flow in the X-Y plane of the fabric or belt and supported web. In other embodiments, the elements described above as being MD and CD aligned elements may be aligned to the opposite axis or aligned off axis from the MD and/or CD directions.

**[00138]** The woven fabric layer 4 is comprised of a woven polymeric fabric with a preferred mesh of between 10-30 frames/cm, a count of 5 to 30 frames/cm, and a caliper from 0.5mm to 1.5mm. This layer preferably has a five shed non numerical consecutive warp-pick sequence (as described in U.S. Patent No. 4,191,609) that is sanded to provide 20 to 50 percent contact area with the layer 2. The fabric or belt 1 with a woven fabric layer 4 of this design is suitable on any TAD or ATMOS asset. Optionally, the woven fabric layer 4 is composed of woven monofilaments or multi-filamentous yarns needled with fine synthetic batt fibers similar to a standard press fabric used in the conventional tissue papermaking press section. The fabric or belt 1 with a woven fabric layer 4 of this design is suitable on any NTT, QRT, or ETAD machine.

**[00139]** FIGS. 6-8 are photographs, FIG. 11 is a cross-sectional view and FIG. 12 is a perspective view of a belt or fabric, generally designated by reference number 300, according to an exemplary embodiment of the present invention. The belt or fabric 300 is produced by laminating an already cured polymer netted layer 318 to a woven fabric layer 310. The polymer netted layer 318 includes CD aligned elements 314 and MD aligned elements 312. The CD aligned elements 314 and the MD aligned elements 312 cross one another with spaces between adjacent elements so as to form openings. As best shown in the

photographs of FIGS. 6-8, both the extruded polymer netting layer 318 and woven layer 310 have non-planar, irregularly shaped surfaces that when laminated together only bond together where the two layers come into direct contact. The lamination results in the extruded polymer layer 318 extending only partially into the woven layer 310 so that any bonding that takes place between the two layers occurs at or near the surface of the woven layer 310. In a preferred embodiment, the extruded polymer layer 318 extends into the woven layer 310 to a depth of 30 microns or less. As shown in FIG. 11, the partial and uneven bonding between the two layers results in formation of air channels 320 that extend in the X-Y plane of the fabric or belt 300. This in turn allows air to travel in the X-Y plane along a sheet (as well as within the fabric or belt 300) being held by the fabric or belt 300 during TAD, UCTAD, or ATMOS processes. Without being bound by theory, it is believed that the fabric or belt 300 removes higher amounts of water due to the longer airflow path and dwell time as compared to conventional designs. In particular, previously known woven and overlaid fabric designs create channels where airflow is restricted in movement in regards to the X-Y direction and channeled in the Z-direction by the physical restrictions imposed by pockets formed by the monofilaments or polymers of the belt. The inventive design allows for airflow in the X-Y direction, such that air can move parallel through the belt and web across multiple pocket boundaries and increase contact time of the airflow within the web to remove additional water. This allows for the use of belts with lower permeability compared to conventional fabrics without increasing the energy demand per ton of paper dried. The air flow in the X-Y plane also reduces high velocity air flow in the Z-direction as the sheet and fabric pass across the molding box, thereby reducing the formation of pin holes in the sheet.

**[00140]** In an exemplary embodiment, the woven layer 310 is composed of polyethylene terephthalate (PET). Conventional non-overlaid structuring fabrics made of PET typically have a failure mode in which fibrillation of the sheet side of the monofilaments occurs due to high pressure from cleaning showers, compression at the pressure roll nip, and heat from the TAD, UCTAD, or ATMOS module. The non-sheet side typically experiences some mild wear and loss of caliper due to abrasion across the paper machine rolls and is rarely the cause of fabric failure. By contrast, the extruded polymer layer 318 is composed of polyurethane, which has higher impact resistance as compared to PET to better resist damage by high pressure showers. It also has higher load capacity in both tension and compression such that it can undergo a change in shape under a heavy load but return to its original shape once the load is removed (which occurs in the pressure roll nip). Polyurethane also has excellent flex fatigue resistance, tensile strength, tear strength, abrasion resistance, and heat resistance. These properties allow the fabric to be durable and run longer on the paper machine than a standard woven fabric. Additionally the woven structure can be sanded to increase the surface area that contacts the extruded polymer layer to increase the total bonded area between the two layers. Varying the degree of sanding of the woven structure can alter the bonded area from 10% to up to 50% of the total surface area of the woven fabric that lies beneath the extruded polymer layer. The preferred bonded area is approximately 20-30% which provides sufficient durability to the fabric without closing excessive amounts of air channels in the X-Y plane of the fabric, which in turn maintains improved drying efficiency compared to conventional fabrics.

**[00141]** FIG. 3 shows a press section according to an exemplary embodiment of the present invention. The press section is similar to the press section described in US Patent

Application Publication No. 2011/0180223 except the press is comprised of suction pressure roll 14 and an extended nip or shoe press 13. A paper web, supported upon a press fabric 10 composed of woven monofilaments or multi-filamentous yarns needled with fine synthetic batt fibers, is transported through this press section nip and transferred to the structuring belt 12. The structuring belt 12 is comprised of a structuring layer of extruded netting or welded polymeric strips made permeable with holes formed by laser drilling (or other suitable mechanical processes) and laminated to a support layer comprised of woven monofilaments or multi-filamentous yarns needled with fine synthetic batt fibers. The support layer is preferably comprised of a material typical of a press fabric used on a conventional tissue machine. The paper web is dewatered through both sides of the sheet into the press fabric 10 and structuring fabric 12 as the web passes through the nip of the press section. The suction pressure roll 14 is preferably a through drilled, blind drilled, and/or grooved polyurethane covered roll.

**[00142]** This press section improves the softness, bulk, and absorbency of web compared to the NTT process. The NTT process flattens the web inside the pocket of the fabric since all the force is being applied by the shoe press to push the web into a fabric pocket that is impermeable or of extremely low permeability to build up hydraulic force to remove the water. The inventive press section uses a press to push the web into a permeable fabric pocket while also drawing the sheet into the fabric pocket using vacuum. This reduces the necessary loading force needed by the shoe press and reduces the buildup of hydraulic pressure, both of which would compress the sheet. The result is that the web within the fabric pocket remains thicker and less compressed, giving the web increased bulk, increased void volume and absorbency, and increased bulk softness. The press section still

retains the simplicity, high speed operation, and low energy cost platform of the NTT, but improves the quality of the product.

**[00143]** FIG. 4 is a cross-sectional view and FIG. 5 is a top planar view of a structuring belt or fabric, generally designated by reference number 100, according to another exemplary embodiment of the present invention. The belt or fabric 100 is multilayered and includes a layer 102 that forms the side of the belt or fabric carrying the paper web, and a woven fabric layer 104 forming the non-paper web contacting side of the belt or fabric. The layer 102 is made of a polymeric material and, in an exemplary embodiment, the layer 102 is made of a sheet of extruded polymeric material. Grooves 103 are formed in the layer 102 (for example, by laser drilling) that extend at an angle (1) relative to the machine direction, and in embodiments the grooves 103 are angled 0.1% to 45% relative to the machine direction, preferably 0.1% to 5% relative to the machine direction, and more preferably 2% to 3% relative to the machine direction. The grooves 103 have a depth (3) of 0.25 mm to 1.0 mm, preferably 0.4 mm to 0.75 mm, and more preferably 0.4 mm to 0.6 mm. The grooves 103 have a square, semicircular or tapered profile, and are spaced 0.1 mm to 1.5 mm apart (4), preferably 0.2 mm to 0.5 mm apart, and more preferably 0.2 mm to 0.3 mm apart. The layer 102 has a thickness (6) of 0.25 mm to 1.5 mm, preferably 0.5 mm to 1.0 mm, and more preferably 0.75 mm to 1.0 mm. The fabric or belt 100 is subjected to punching, drilling or laser drilling to achieve an air permeability of 20 cfm to 200 cfm, preferably 20 cfm to 100 cfm, and more preferably 10 cfm to 50 cfm.

**[00144]** In a variation of the exemplary embodiment shown in FIG. 4, additional grooves are formed in the layer 102 which extend in the cross direction. Portions of the layer 102

between the cross direction grooves are lower than portions between the machine direction grooves, so that the portions between the machine direction grooves form elevated elements in the surface of the layer 102 in contact with the web, similar to the embodiment shown in FIG. 1.

**[00145]** The following example and test results demonstrate the advantages of the present invention.

**[00146] SOFTNESS TESTING**

**[00147]** Softness of a 1-ply tissue web was determined using a Tissue Softness Analyzer (TSA), available from EMTECH Electronic GmbH of Leipzig, Germany. A punch was used to cut out three 100 cm<sup>2</sup> round samples from the web. One of the samples was loaded into the TSA, clamped into place, and the Tissue Basesheet II algorithm was selected from the list of available softness testing algorithms displayed by the TSA. After inputting parameters for the sample, the TSA measurement program was run. The test process was repeated for the remaining samples and the results for all the samples were averaged.

**[00148] STRETCH & MD, CD, AND WET CD TENSILE STRENGTH TESTING**

**[00149]** An Instron 3343 tensile tester, manufactured by Instron of Norwood, MA, with a 100N load cell and 25.4 mm rubber coated jaw faces was used for tensile strength measurement. Prior to measurement, the Instron 3343 tensile tester was calibrated. After calibration, 8 strips of 1-ply product, each one inch by four inches, were provided as samples for each test. The strips were cut in the MD direction when testing MD and in the CD direction when testing CD. One of the sample strips was placed in between the upper

jaw faces and clamp, and then between the lower jaw faces and clamp with a gap of 2 inches between the clamps. A test was run on the sample strip to obtain tensile and stretch. The test procedure was repeated until all the samples were tested. The values obtained for the eight sample strips were averaged to determine the tensile strength of the tissue.

**[00150] BASIS WEIGHT**

**[00151]** Using a dye and press, six 76.2mm by 76.2mm square samples were cut from a 1-ply product being careful to avoid any web perforations. The samples were placed in an oven at 105 deg C for 5 minutes before being weighed on an analytical balance to the fourth decimal point. The weight of the sample in grams was divided by  $(0.0762\text{m})^2$  to determine the basis weight in grams/m<sup>2</sup>.

**[00152] CALIPER TESTING**

**[00153]** A Thwing-Albert ProGage 100 Thickness Tester, manufactured by Thwing Albert of West Berlin, NJ was used for the caliper test. Eight 100mm x 100mm square samples were cut from a 1-ply product. The samples were then tested individually and the results were averaged to obtain a caliper result for the base sheet.

**[00154] EXAMPLE 1**

**[00155]** A 1-ply creped tissue web was produced on a Through Air Dried paper machine with a triple layer headbox and dual TAD drums, with the tissue web having the following product attributes: Basis Weight 20.8 g/m<sup>2</sup>, Caliper 0.305 mm, MD tensile of 69.7 N/m, CD tensile of 43.7 N/m, an MD stretch of 22.4%, a CD stretch of 8.5%, and a 96 TSA.

**[00156]** The tissue web was multilayered with the fiber and chemistry of each layer selected and prepared individually to maximize product quality attributes of softness and strength. The first exterior layer, which was the layer that contacted the Yankee dryer, was prepared using 100% eucalyptus with 0.25 kg/ton of a synthetic polymer dry strength agent DPD-589 (Ashland, 500 Hercules Road, Wilmington DE, 19808). The interior layer was composed of 40% northern bleached softwood kraft fibers, 60% eucalyptus fibers, and 0.75 kg/ton of T526, a softener/debonder (EKA Chemicals Inc., 1775 West Oak Commons Court, Marietta, GA, 30062). The second exterior layer was composed of 40% northern bleached softwood kraft fibers, 60% eucalyptus fibers and with 1.875 kg/ton of a synthetic polymer dry strength agent DPD-589 at 3.0 kg/ton. The softwood was refined at 30 kwh/ton to impart the necessary tensile strength.

**[00157]** The fiber and chemicals mixtures were diluted to a solids of 0.5% consistency and fed to separate fan pumps which delivered the slurry to a triple layered headbox. The headbox pH was controlled to 7.0 by addition of sodium bicarbonate to the thick stock before the fan pumps. The headbox deposited the slurry to a nip formed by a forming roll, an outer forming wire, and inner forming wire where the wires were running at a speed of 1060 m/min. The slurry was drained through the outer wire, which was a KT194-P design supplied by Asten Johnson (4399 Corporate Rd, Charleston, SC), to aid with drainage, fiber support, and web formation. When the fabrics separated, the web followed the inner forming wire and was dried to approximately 27% solids using a series of vacuum boxes and a steam box.

**[00158]** The web was then transferred to a structuring fabric running at 1060 m/min with the aid of a vacuum box to facilitate fiber penetration into the structuring fabric to enhance bulk softness and web imprinting. The structuring fabric included a layer made from a netted tube of extruded polymer with a thickness of 0.5 mm, as shown in Fig 1, with openings being regularly recurrent and distributed in the longitudinal (MD) and cross direction (CD). This layer was the structuring layer of the fabric. The openings were circular with a diameter of 0.63 mm. The MD aligned portion of the netting of the layer extended 0.16 mm above the top plane of the CD aligned portion of the netting of the layer. The width of the MD aligned portion of the netting of the layer was 0.26 mm. The width of the CD aligned portion of the netting of the layer was 0.46 mm. The layer was supported by woven fabric layer, which was a Prolux N005, 5 shed 1,3,5,2,4 warp pick sequence woven polymer fabric sanded to 27% contact area, supplied by Albany (216 Airport Drive Rochester, NH, USA) with a caliper of 0.775 mm. The two layers were laminated together using ultrasonic welding.

**[00159]** The web was dried with the aid of two TAD hot air impingement drums to 81% moisture before transfer to the Yankee dryer. The web was held in intimate contact with the Yankee surface using an adhesive coating chemistry. The Yankee dryer was provided steam at 300 kPa while the installed hot air impingement hood over the Yankee dryer blew heated air at 125 deg C. The web was creped from the Yankee dryer at 13.2% crepe at 98.2% dryness using a steel blade at a pocket angle of 90 degrees.

**[00160] Example 2**

**[00161]** A 1-ply creped tissue web was produced on a Through Air Dried paper machine with a triple layer headbox and dual TAD drums, with the tissue web having the following product attributes: Basis Weight 20.6 g/m<sup>2</sup>, Caliper 0.380 mm, MD tensile of 68.8 N/m, CD tensile of 37.9 N/m, an MD stretch of 21.1%, a CD stretch of 10.8%, and a 97.1 TSA.

**[00162]** The tissue web was multilayered with the fiber and chemistry of each layer selected and prepared individually to maximize product quality attributes of softness and strength. The first exterior layer, which was the layer that contacted the Yankee dryer, was prepared using 75% eucalyptus and 25% northern bleached softwood kraft fibers with 1.25 kg/ton of glyoxylated polyacrylamide, Hercobond 1194 and 0.25 kg/ton of a polyvinylamine retention aid, Hercobond 6950 (Solenis, 500 Hercules Road, Wilmington DE, 19808) and 0.75 kg/ton of Redibond 2038 (Ingredion 5 Westbrook Corporate Center Westchester, IL 60154). The interior layer was composed of 25% northern bleached softwood kraft fibers, 75% eucalyptus fibers, and 0.75 kg/ton of T526, a softener/debonder (EKA Chemicals Inc., 1775 West Oak Commons Court, Marietta, GA, 30062) and 1.25 kg/ton of Hercobond 1194. The second exterior layer was composed of 100% northern bleached softwood kraft fibers with 2.25 kg/ton of Redibond 2038 and 0.25 kg/ton of Hercobond 6950. The softwood was refined at 13 kwh/ton to impart the necessary tensile strength.

**[00163]** The fiber and chemicals mixtures were diluted to a solids of 0.5% consistency and fed to separate fan pumps which delivered the slurry to a triple layered headbox. The headbox pH was controlled to 7.0 by addition of sodium bicarbonate to the thick stock before the fan pumps. The headbox deposited the slurry to a nip formed by a forming roll, an outer forming wire, and inner forming wire where the wires were running at a speed of

1060 m/min. The slurry was drained through the outer wire, which was a KT194-P design supplied by Asten Johnson (4399 Corporate Rd, Charleston, SC ), to aid with drainage, fiber support, and web formation. When the fabrics separated, the web followed the inner forming wire and was dried to approximately 27% solids using a series of vacuum boxes and a steam box.

**[00164]** The web was then transferred to a structuring fabric running at 1060 m/min with the aid of a vacuum box to facilitate fiber penetration into the structuring fabric to enhance bulk softness and web imprinting. The structuring fabric included a layer made from a netted tube of extruded polymer with a thickness of 0.7 mm, as shown in Fig 1, with openings being regularly recurrent and distributed in the longitudinal (MD) and cross direction (CD). This layer was the structuring layer of the fabric. The openings were circular with a diameter of 0.75 mm. The MD aligned portion of the netting of the layer extended 0.25 mm above the top plane of the CD aligned portion of the netting of the layer. The width of the MD aligned portion of the netting of the layer was 0.52 mm. The width of the CD aligned portion of the netting of the layer was 0.62 mm. The layer was supported by woven fabric layer, which was a Prolux N005, 5 shed 1,3,5,2,4 warp pick sequence woven polymer fabric sanded to 27% contact area, supplied by Albany (216 Airport Drive Rochester, NH, USA) with a caliper of 0.775 mm. The two layers were laminated together using ultrasonic welding.

**[00165]** The web was dried with the aid of two TAD hot air impingement drums to approximately 80% moisture before transfer to the Yankee dryer. The web was held in intimate contact with the Yankee surface using an adhesive coating chemistry. The Yankee

dryer was provided steam at 300 kPa while the installed hot air impingement hood over the Yankee dryer blew heated air at 105 deg C. The web was creped from the Yankee dryer at 13% crepe at approximately 98% dryness using a steel blade at a pocket angle of 90 degrees.

**[00166] Comparative Example**

**[00167]** A 1-ply creped tissue web was produced on a Through Air Dried paper machine with a triple layer headbox and dual TAD drums, with the tissue web having the following product attributes: Basis Weight 20.4 g/m<sup>2</sup>, Caliper 0.336 mm, MD tensile of 76.3 N/m, CD tensile of 40.6 N/m, an MD stretch of 22.9%, a CD stretch of 10.1%, and a 90.9 TSA.

**[00168]** The tissue web was multilayered with the fiber and chemistry of each layer selected and prepared individually to maximize product quality attributes of softness and strength. The first exterior layer, which was the layer that contacted the Yankee dryer, was prepared using 75% eucalyptus and 25% northern bleached softwood kraft fibers with 1.25 kg/ton of glyoxylated polyacrylamide, Hercobond 1194 and 0.25 kg/ton of a polyvinylamine retention aid, Hercobond 6950 (Solenis, 500 Hercules Road, Wilmington DE, 19808) and 1.25 kg/ton of Redibond 2038 (Ingredion 5 Westbrook Corporate Center Westchester, IL 60154). The interior layer was composed of 25% northern bleached softwood kraft fibers, 75% eucalyptus fibers, and 0.75 kg/ton of T526, a softener/debonder (EKA Chemicals Inc., 1775 West Oak Commons Court, Marietta, GA, 30062) and 1.25 kg/ton of Hercobond 1194. The second exterior layer was composed of 100% northern bleached softwood kraft fibers with 3.75 kg/ton of Redibond 2038 and 0.25 kg/ton of Hercobond 6950. Softwood was refined at 16 kwh/ton to impart the necessary tensile strength.

**[00169]** The fiber and chemicals mixtures were diluted to a solids of 0.5% consistency and fed to separate fan pumps which delivered the slurry to a triple layered headbox. The headbox pH was controlled to 7.0 by addition of sodium bicarbonate to the thick stock before the fan pumps. The headbox deposited the slurry to a nip formed by a forming roll, an outer forming wire, and inner forming wire where the wires were running at a speed of 1060 m/min. The slurry was drained through the outer wire, which was a KT194-P design supplied by Asten Johnson (4399 Corporate Rd, Charleston, SC ), to aid with drainage, fiber support, and web formation. When the fabrics separated, the web followed the inner forming wire and was dried to approximately 27% solids using a series of vacuum boxes and a steam box.

**[00170]** The web was then transferred to a structuring fabric running at 1060 m/min with the aid of a vacuum box to facilitate fiber penetration into the structuring fabric to enhance bulk softness and web imprinting. The structured fabric was a Prolux 005 design supplied by Albany (216 Airport Drive Rochester, NH 03867 USA) and was a 5 shed design with a warp pick sequence of 1,3,5,2,4, a 17.8 by 11.1 yarn/cm Mesh and Count, a 0.35 mm warp monofilament, a 0.50 mm weft monofilament, a 1.02 mm caliper, with a 640 cfm and a knuckle surface that was sanded to impart 27% contact area with the Yankee dryer.

**[00171]** The web was dried with the aid of two TAD hot air impingement drums to approximately 80% moisture before transfer to the Yankee dryer. The web was held in intimate contact with the Yankee surface using an adhesive coating chemistry. The Yankee dryer was provided steam at 300 kPa while the installed hot air impingement hood over the Yankee dryer blew heated air at 110 deg C. The web was creped from the Yankee dryer at

13.0% crepe at approximately 98% dryness using a steel blade at a pocket angle of 90 degrees.

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**[00172]** A comparison of Example 2 with the Comparative Example demonstrates that the use of an overlaid fabric of the present invention allows for use of a lower temperature through the TAD section to arrive at the same sheet dryness. Example 1 differs from Example 2 and the Comparative Example in that Example 1 used less hardwood. The furnish mixtures were the same between Example 2 and the Comparative Example and the basis weight and quality of the sheet were also very similar.

**[00173]** Now that embodiments of the present invention have been shown and described in detail, various modifications and improvements thereon will become readily apparent to those skilled in the art. Accordingly, the spirit and scope of the present invention is to be construed broadly and not limited by the foregoing specification.

## CLAIMS:

1. A fabric or belt for a papermaking machine comprising:  
a first layer that defines a web contacting surface, the first layer being made of extruded polymer and comprising:  
a plurality of first elements aligned in a first direction;  
a plurality of second elements aligned in a second direction and extending over the plurality of first elements; and  
a plurality of open portions defined by the plurality of first and second elements;  
and  
a second layer made of woven fabric that supports the first layer,  
wherein the first layer is bonded to the second layer so that the first layer extends only partially through the second layer and an interface formed between the first and second layers comprises airflow channels that extend in a plane parallel to the first and second layers.
2. The fabric or belt of claim 1, wherein the interface between the first and second layers comprises bonded and non-bonded portions.
3. The fabric or belt of claim 1, wherein the first layer extends into the second layer by an amount of 30  $\mu\text{m}$  or less.
4. The fabric or belt of claim 1, wherein the first layer has a thickness of 0.25 mm to 1.7 mm.
5. The fabric or belt of claim 1, wherein the first layer has a thickness of 0.4 mm to 0.75 mm.
6. The fabric or belt of claim 1, wherein the first layer has a thickness of 0.5 mm to 0.6 mm.

7. The fabric or belt of claim 1, wherein the plurality of open portions repeat across the first layer in both machine and cross directions at regular intervals.

8. The fabric or belt of claim 1, wherein the plurality of open portions are rectangular-shaped open portions.

9. The fabric or belt of claim 8, wherein the rectangular-shaped open portions are defined by sides with a length of 0.25 mm to 1.0 mm.

10. The fabric or belt of claim 8, wherein the rectangular-shaped open portions are defined by sides with a length of 0.4 mm to 0.75 mm.

11. The fabric or belt of claim 8, wherein the rectangular-shaped open portions are defined by sides with a length of 0.5 mm to 0.7 mm.

12. The fabric or belt of claim 8, wherein the plurality of open portions are square-shaped open portions.

13. The fabric or belt of claim 1, wherein the plurality of open portions are circular-shaped open portions.

14. The fabric or belt of claim 13, wherein the diameter of the circular-shaped open portions is 0.25 mm to 1.0 mm.

15. The fabric or belt of claim 13, wherein the diameter of the circular-shaped open portions is 0.4 mm to 0.75 mm.

16. The fabric or belt of claim 13, wherein the diameter of the circular-shaped open portions is 0.1 mm to 0.7 mm.

17. The fabric or belt of claim 1, wherein the plurality of second elements extend above the plurality of first elements by an amount of 0.05 mm to 0.40 mm.

18. The fabric or belt of claim 1, wherein the plurality of second elements extend above the plurality of first elements by an amount of 0.1 mm to 0.3 mm.

19. The fabric or belt of claim 1, wherein the plurality of second elements extend above the plurality of first elements by an amount of 0.1 mm to 0.2 mm.

20. The fabric or belt of claim 1, wherein the plurality of second elements have a width of 0.1 mm to 0.7 mm.

21. The fabric or belt of claim 1, wherein the plurality of second elements have a width of 0.2 mm to 0.4 mm.

22. The fabric or belt of claim 1, wherein the plurality of second elements have a width of 0.25 mm to 0.3 mm.

23. The fabric or belt of claim 1, wherein the plurality of first elements have a thickness of 0.15 mm to 0.75 mm.

24. The fabric or belt of claim 1, wherein the plurality of first elements have a thickness of 0.3 mm to 0.6 mm.

25. The fabric or belt of claim 1, wherein the plurality of first elements have a thickness of 0.4 mm to 0.6 mm.

26. The fabric or belt of claim 1, wherein the plurality of first elements have a width of 0.25 mm to 1.0 mm.

27. The fabric or belt of claim 1, wherein the plurality of first elements have a width of 0.3 mm to 0.5 mm.

28. The fabric or belt of claim 1, wherein the plurality of first elements have a width of 0.4 mm to 0.5 mm.

29. The fabric or belt of claim 1, wherein the first layer is made of polymer or copolymer.

30. The fabric or belt of claim 29, wherein the first layer is made of an extruded netting tube.

31. The fabric or belt of claim 30, wherein the extruded netting tube is stretched to orient the polymer or copolymer.

32. The fabric or belt of claim 29, wherein the first layer is made of a perforated sheet.

33. The fabric or belt of claim 32 wherein the perforated sheet is stretched to orient the polymer or copolymer.

34. The fabric or belt of claim 32, wherein the perforated sheet is seamed using thermal, laser, infrared or ultraviolet seaming.

35. The fabric or belt of claim 1, wherein the second layer comprises woven polymeric monofilaments.

36. The fabric or belt of claim 1, wherein the second layer comprises woven monofilaments or multi-filamentous yarns needled with fine synthetic batt fibers.

37. The fabric or belt of claim 1, wherein the second layer has a 5 shed weave with a non-numerical warp pick sequence.
38. The fabric or belt of claim 1, wherein the second layer has a mesh of 10 to 30 frames/cm.
39. The fabric or belt of claim 1, wherein the second layer has a mesh of 15 to 25 frames/cm.
40. The fabric or belt of claim 1, wherein the second layer has a mesh of 17 to 22 frames/cm.
41. The fabric or belt of claim 1, wherein the second layer has a count of 5 to 30 frames/cm.
42. The fabric or belt of claim 1, wherein the second layer has a count of 10 to 20 frames/cm.
43. The fabric or belt of claim 1, wherein the second layer has a count of 15 to 20 frames/cm.
44. The fabric or belt of claim 1, wherein the second layer has a caliper of 0.5 mm to 1.5 mm.
45. The fabric or belt of claim 1, wherein the second layer has a caliper of 0.5 mm to 1.0 mm.
46. The fabric or belt of claim 1, wherein the second layer has a caliper of 0.5 mm to 0.75 mm.

47. The fabric or belt of claim 1, wherein the second layer is bonded to the first layer by thermal, ultrasonic, ultraviolet or infrared welding.

48. The fabric or belt of claim 1, wherein the second layer is bonded to the first layer with a 20% to 50% contact area.

49. The fabric or belt of claim 1, wherein the second layer is bonded to the first layer with a 20% to 30% contact area.

50. The fabric or belt of claim 1, wherein the second layer is bonded to the first layer with a 25% to 30% contact area.

51. The fabric or belt of claim 1, wherein the fabric or belt has an air permeability of 20 cfm to 300 cfm.

52. The fabric or belt of claim 1, wherein the fabric or belt has an air permeability of 100 cfm to 250 cfm.

53. The fabric or belt of claim 1, wherein the fabric or belt has an air permeability of 200 cfm to 250 cfm.

54. The fabric or belt of claim 1, wherein the fabric or belt is a structuring fabric configured for use on a papermaking machine.

55. The fabric or belt of claim 54, wherein the papermaking machine is a Through Air Dried, ATMOS, NTT, QRT or ETAD tissue making machine.

56. The fabric or belt of claim 1, wherein the fabric or belt is a forming fabric configured for use on a papermaking machine.

57. The fabric or belt of claim 1, wherein the plurality of second elements extend below the plurality of first elements.

58. The fabric or belt of claim 57, wherein the plurality of second elements extend below the plurality of first elements by less than 0.40 mm.

59. The fabric or belt of claim 57, wherein the plurality of second elements extend below the plurality of first elements by 0.1 mm to 0.3 mm.

60. The fabric or belt of claim 57, wherein the plurality of second elements extend below the plurality of first elements by 0.1 mm to 0.2 mm.

61. The fabric or belt of claim 1, wherein the first direction is substantially parallel to a machine cross direction.

62. The fabric or belt of claim 61, wherein the second direction is substantially parallel to a machine direction.

63. The fabric or belt of claim 1, wherein the first direction is substantially parallel to a machine direction.

64. The fabric or belt of claim 63, wherein the second direction is substantially parallel to a machine cross direction.

65. A fabric or belt for a papermaking machine comprising:  
a first layer that defines a web contacting surface, the first layer being made of extruded polymer and comprising:

a plurality of first elements aligned in a first direction;

a plurality of second elements aligned in a second direction and extending over the plurality of first elements; and

a plurality of open portions defined by the plurality of first and second elements;  
and  
a second layer made of woven fabric that supports the first layer,  
wherein the first layer is bonded to the second layer so as to form an interface between the first and second layers that comprises bonded and unbonded portions and airflow channels that extend in a plane parallel to the first and second layers.

66. The fabric or belt of claim 65, wherein the first layer extends only partially through the second layer.

67. The fabric or belt of claim 66, wherein the first layer extends into the second layer by an amount of 30  $\mu\text{m}$  or less.

68. A fabric or belt for a papermaking machine comprising:  
a first layer that defines a web contacting surface, the first layer comprising a plurality of grooves aligned substantially in the machine direction; and  
a second layer made of woven fabric that supports the first layer,  
wherein the first layer is bonded to the second layer so as to form an interface between the first and second layers that comprises bonded and unbonded portions and airflow channels that extend in a plane parallel to the first and second layers.

69. The fabric or belt of claim 68, wherein the plurality of grooves are angled 0.1% to 45% relative to the machine direction.

70. The fabric or belt of claim 68, wherein the plurality of grooves are angled 0.1% to 5% relative to the machine direction.

71. The fabric or belt of claim 68, wherein the plurality of grooves are angled 2% to 3% relative to the machine direction.

72. The fabric or belt of claim 68, wherein the plurality of grooves have a depth of

0.25 mm to 1.0mm.

73. The fabric or belt of claim 68, wherein the plurality of grooves have a depth of 0.4 mm to 0.75mm.

74. The fabric or belt of claim 68, wherein the plurality of grooves have a depth of 0.4 mm to 0.6mm.

75. The fabric or belt of claim 68, wherein the plurality of grooves have a square, semicircular or tapered cross section.

76. The fabric or belt of claim 68, wherein the plurality of grooves are spaced 0.1 mm to 1.5 mm apart from each other.

77. The fabric or belt of claim 68, wherein the plurality of grooves are spaced 0.2 mm to 0.5 mm apart from each other.

78. The fabric or belt of claim 68, wherein the plurality of grooves are spaced 0.2 mm to 0.3 mm apart from each other.

79. The fabric or belt of claim 68, wherein the plurality of grooves are formed by laser drilling.

80. The fabric or belt of claim 68, wherein the fabric or belt is subjected to punching, drilling or laser drilling to achieve an air permeability of 20 cfm to 200 cfm.

81. The fabric or belt of claim 80, wherein the fabric or belt has an air permeability of 20 cfm to 100 cfm.

82. The fabric or belt of claim 80, wherein the fabric or belt has an air permeability of 10 cfm to 50 cfm.

83. A fabric or belt for a papermaking machine comprising:  
first layer that defines a web contacting surface, the first layer comprising:  
a plurality of first elements aligned in a cross direction, the plurality of first elements having a thickness of 0.3 mm to 0.6 mm and a width of 0.4 mm to 0.5 mm;  
a plurality of second elements aligned in a machine direction and extending over the plurality of first elements by an amount of 0.1 mm to 0.2 mm and having a width of 0.25 mm to 0.3 mm; and  
a plurality of open portions defined by the plurality of first and second elements and that repeat across the at least one nonwoven layer in both the machine and cross directions at regular intervals, the plurality of open portions being square shaped and defined by sides with a length of 0.5 mm to 0.7 mm; and  
a woven fabric layer that supports the at least one layer, wherein the fabric or belt has an air permeability of 20 cfm to 300 cfm.

84. A fabric or belt for a papermaking machine comprising:  
at least one layer that defines a web contacting surface, the at least one layer comprising:  
a plurality of first elements aligned in a cross direction, the plurality of first elements having a thickness of 0.3 mm to 0.6 mm and a width of 0.4 mm to 0.5 mm;  
a plurality of second elements aligned in a machine direction and extending over the plurality of first elements by an amount of 0.1 mm to 0.2 mm and having a width of 0.25 mm to 0.3 mm; and  
a plurality of open portions defined by the plurality of first and second elements and that repeat across the at least one layer in both the machine and cross directions at regular intervals, the plurality of open portions being circular shaped with a diameter of 0.5 mm to 0.7 mm; and  
a woven fabric layer that supports the at least one layer, wherein the fabric or belt has an air permeability of 20 cfm to 300 cfm.

85. A method of forming a tissue product comprising:

depositing a nascent paper web onto a forming fabric of a papermaking machine so as to form a paper web;

at least partially dewatering the paper web through a structuring fabric of a press section of the papermaking machine, wherein the structuring fabric comprises:

a first layer that defines a web contacting surface, the first layer being made of extruded polymer and comprising:

a plurality of first elements aligned in a first direction;

a plurality of second elements aligned in a second direction and extending over the plurality of first elements; and

a plurality of open portions defined by the plurality of first and second elements; and

a second layer made of woven fabric that supports the first layer,

wherein the first layer is bonded to the second layer so that the first layer extends only partially through the second layer and an interface formed between the first and second layers comprise airflow channels that extend in a plane parallel to the first and second layers; and

drying the at least partially dewatered paper web at a drying section of the papermaking machine.

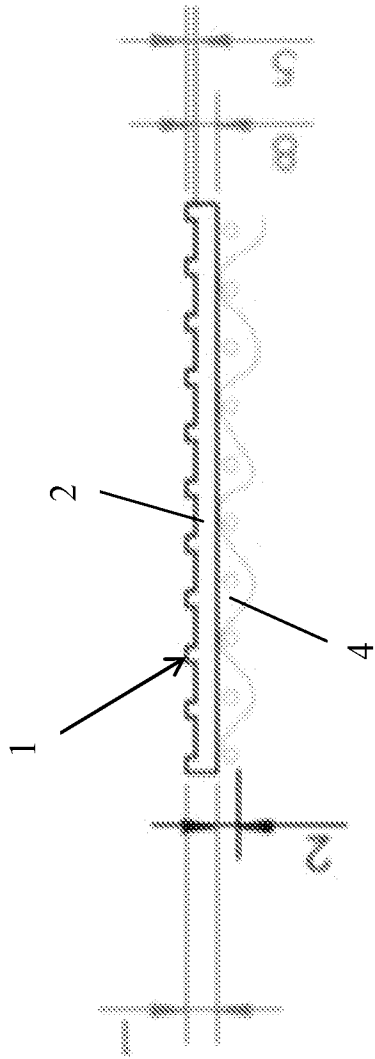


FIG. 1

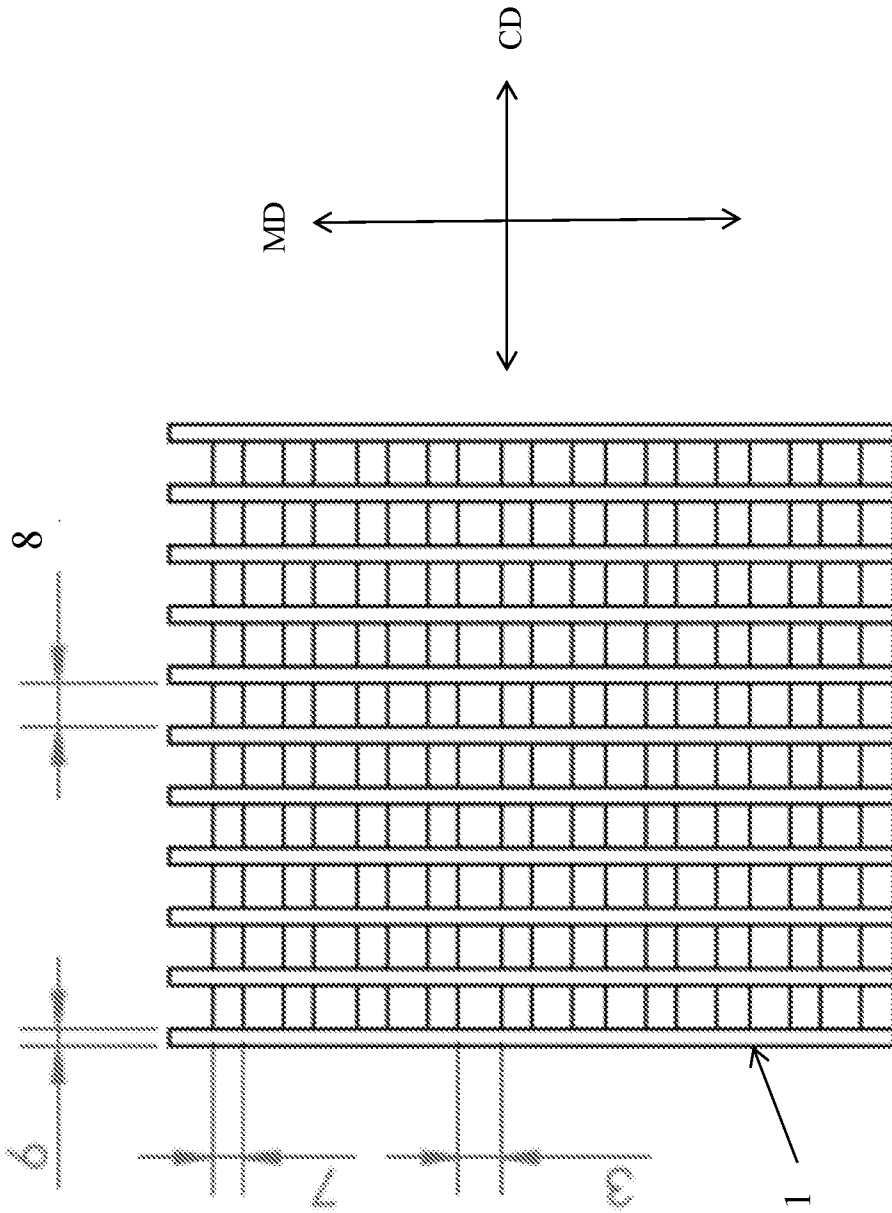
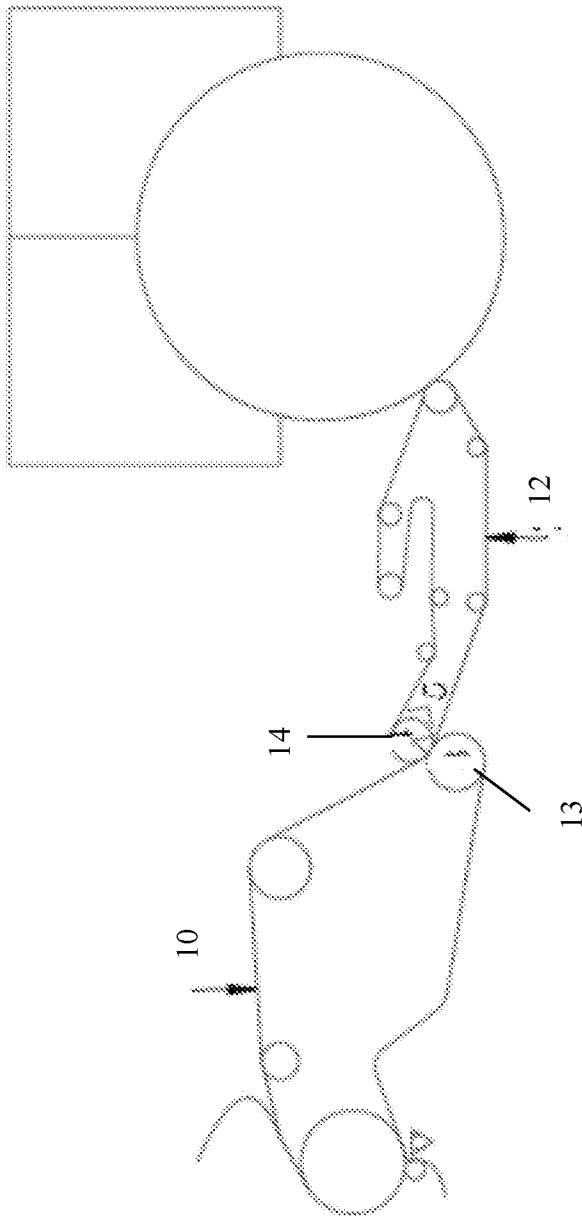


FIG. 2



**FIG. 3**

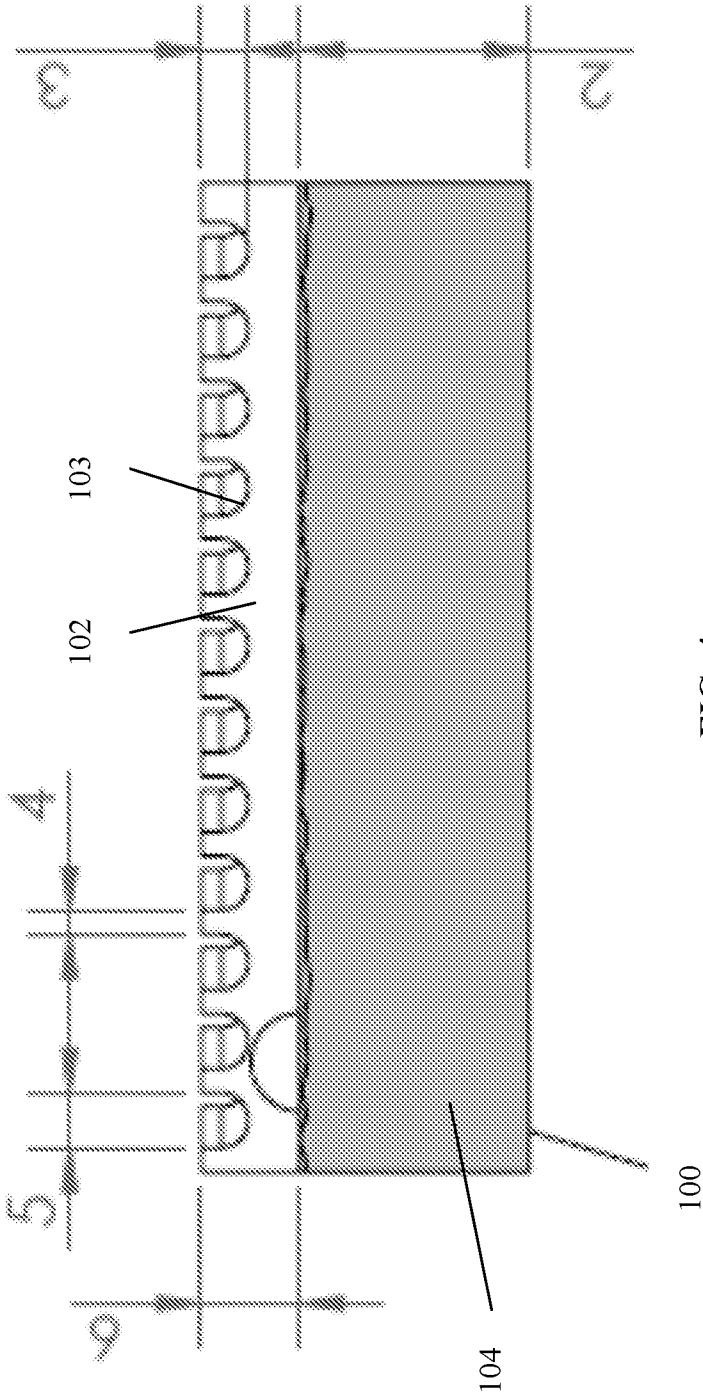


FIG. 4

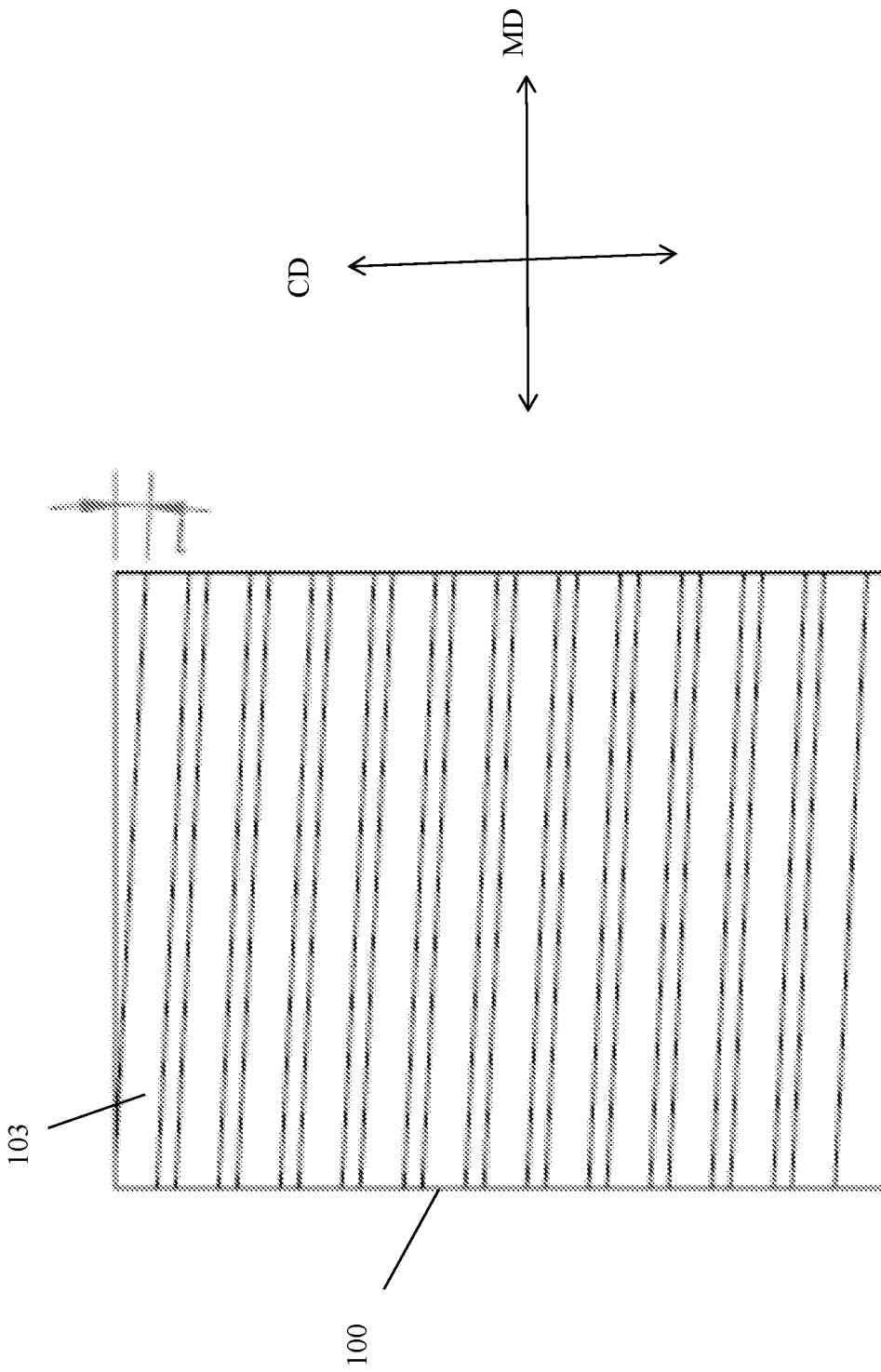


FIG. 5

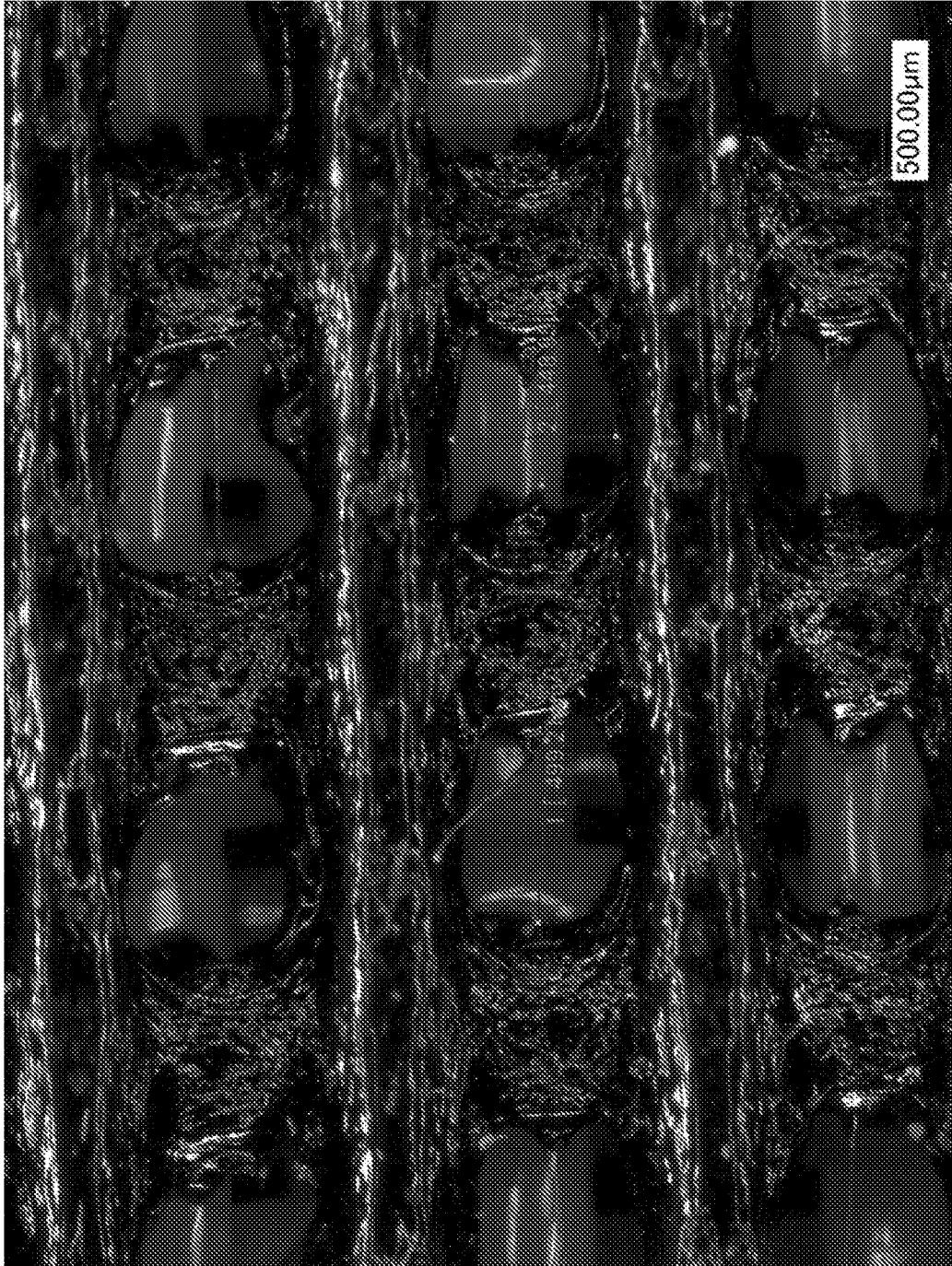


FIG. 6

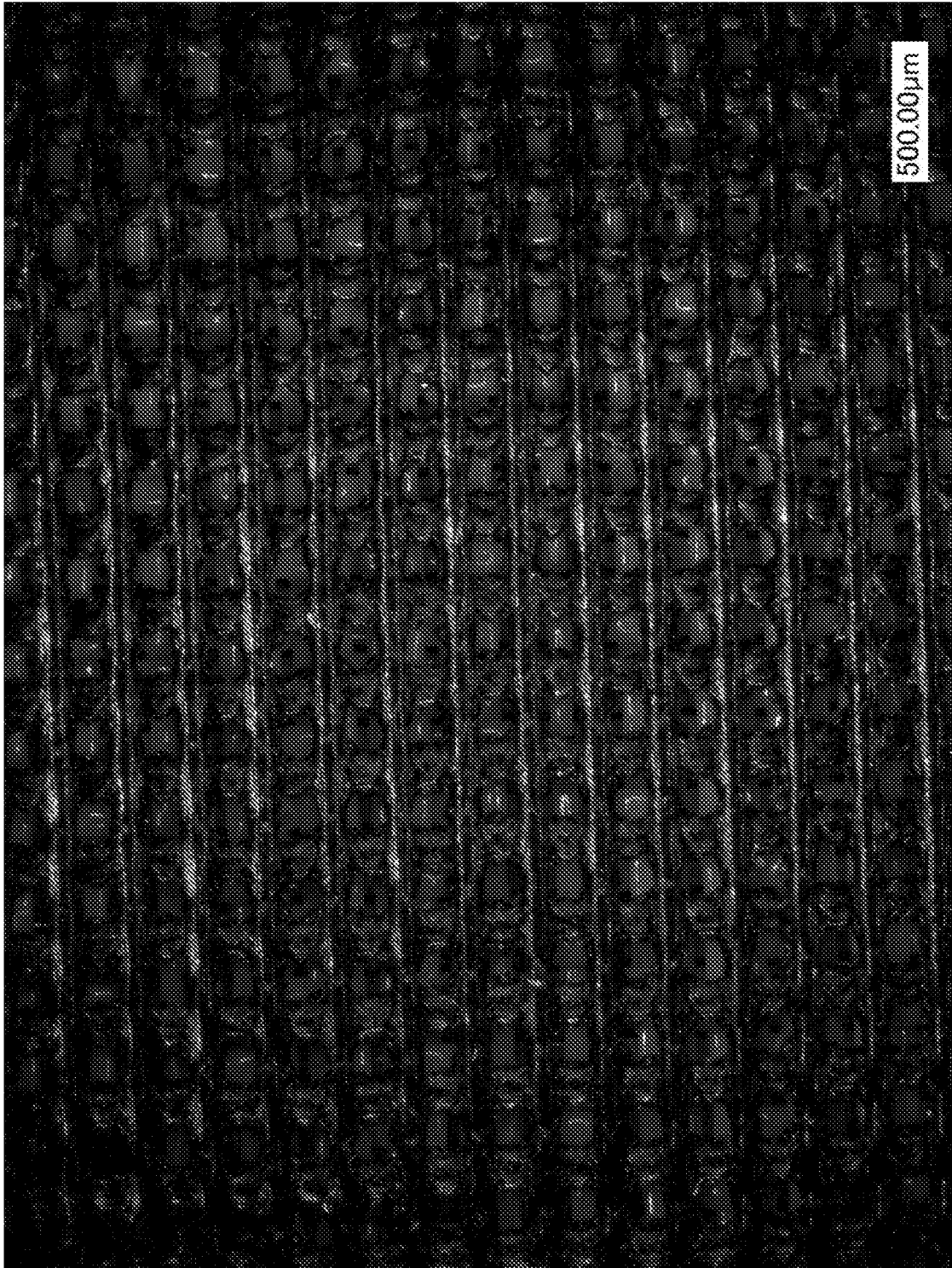


FIG. 7

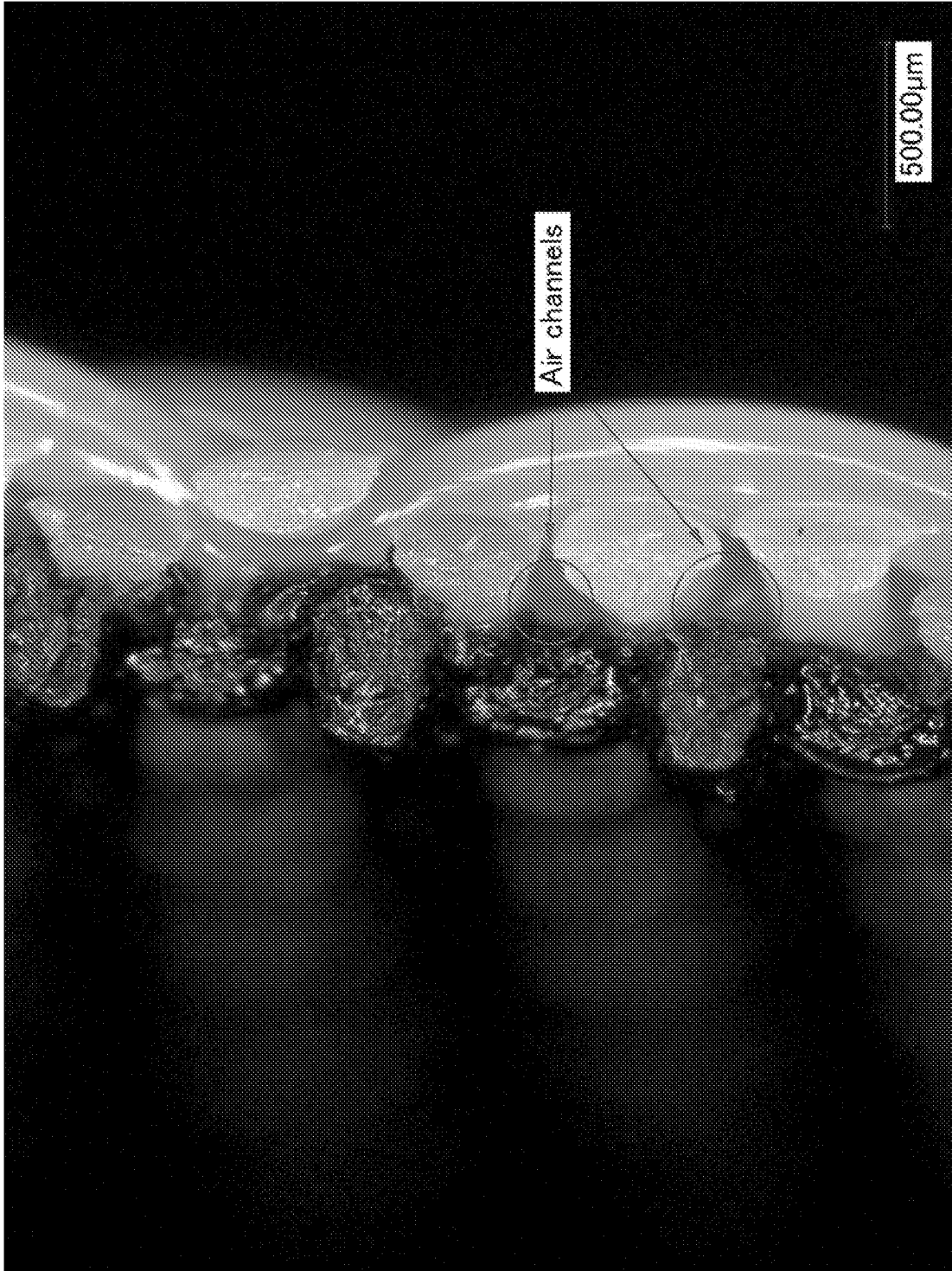
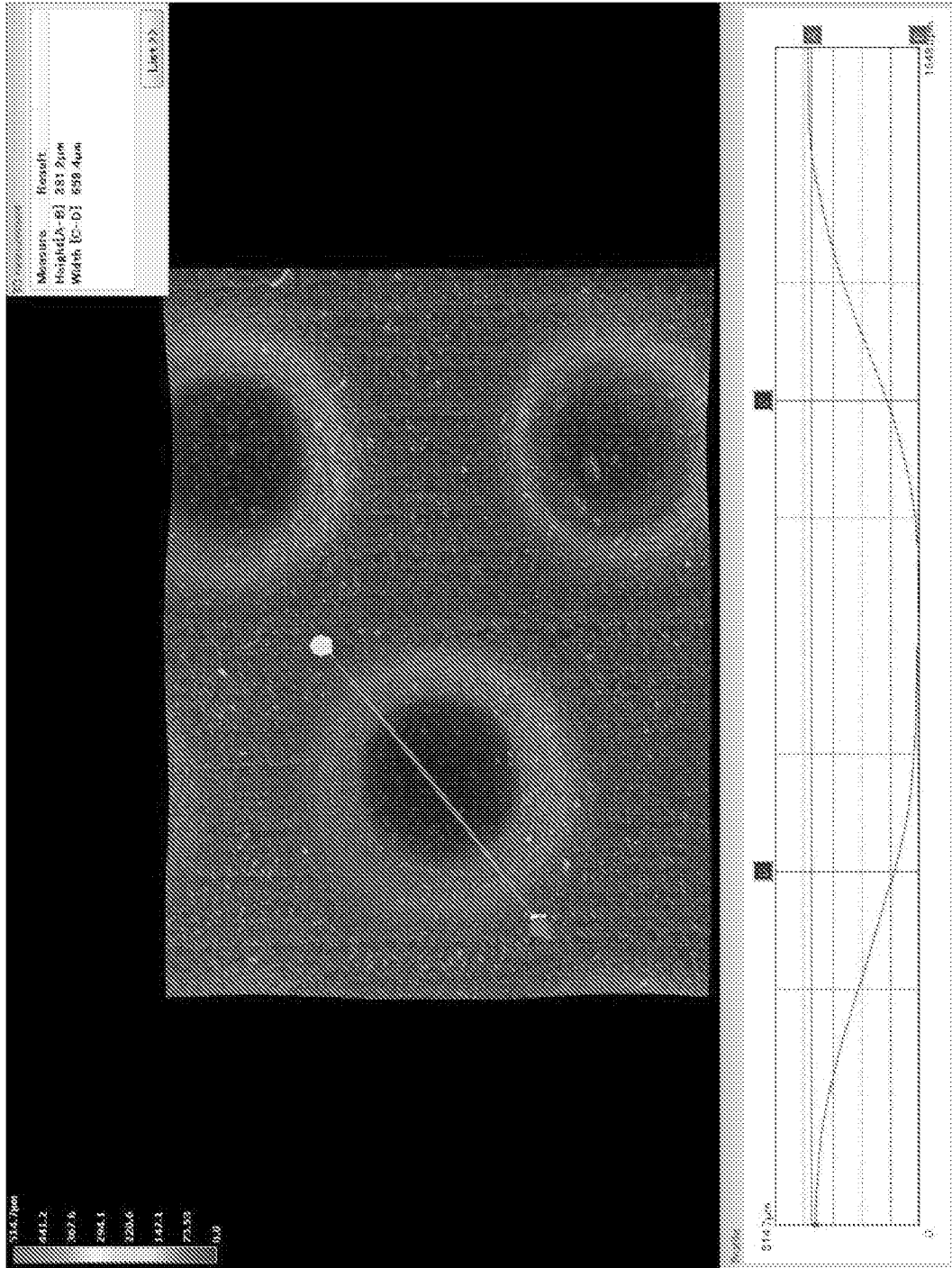


FIG. 8



CONVENTIONAL ART

FIG. 9

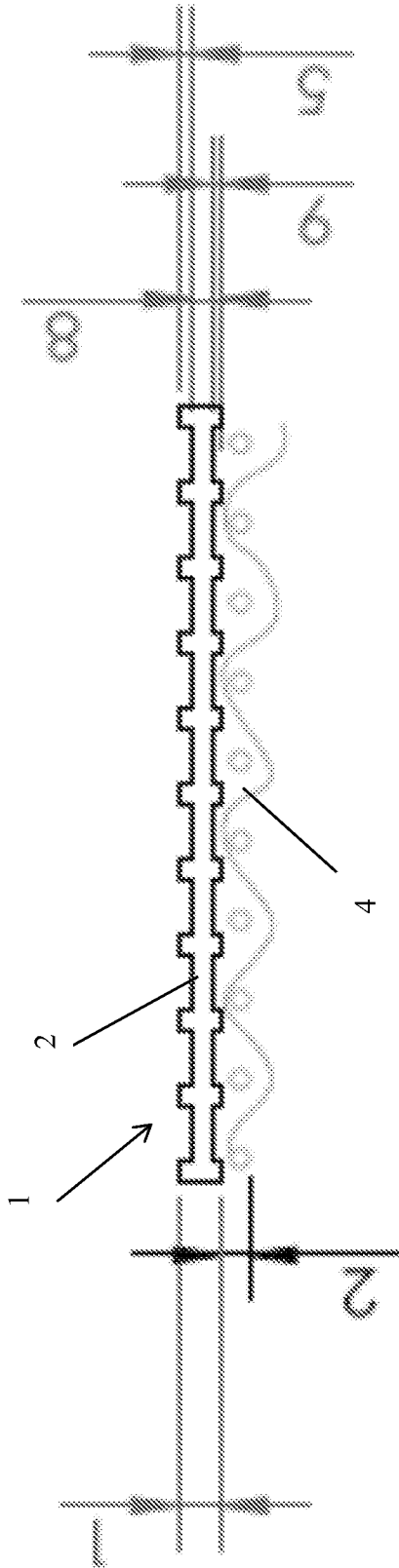


FIG. 10

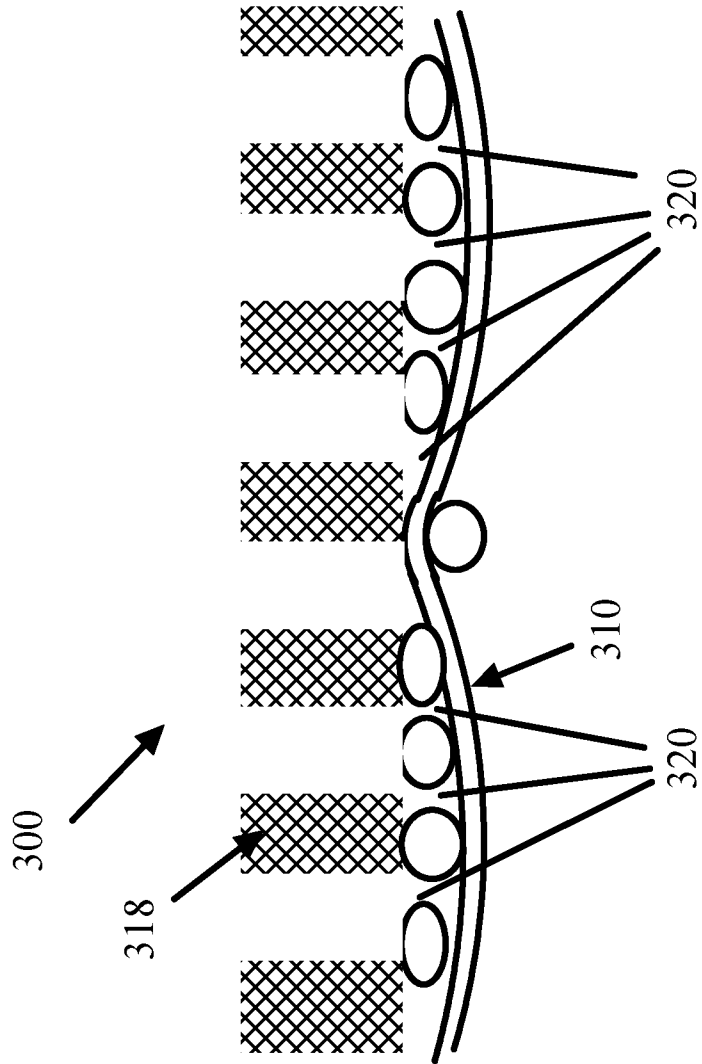


FIG. 11

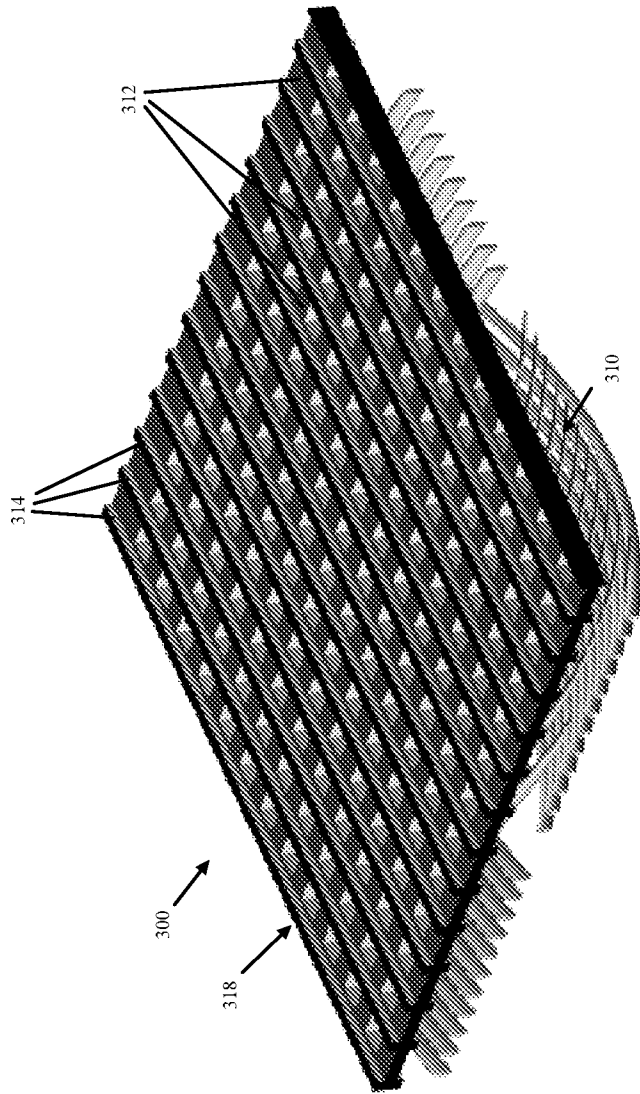


FIG. 12

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 17/17705

A. CLASSIFICATION OF SUBJECT MATTER  
 IPC(8) - D21F 1/00, D21F 7/12, D21F 1/10, D21F 3/00, D21F 7/08 (2017.01)  
 CPC - D21F 1/00, D21F 7/12, D21F 7/083, D21F 1/0027, D21F 1/10, D21F 3/00

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

See Search History Document

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

See Search History Document

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

See Search History Document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y --- A	US 2014/0272269 A1 (Hansen) 18 September 2014 (18.09.2014), entire document, especially Figs. 2, 7 paras. [0001-0006, 0043-0044, 0050-0055, 0061-63]	1-2, 4-12, 17-36, 47, 54-56, 61-66, 85 ----- 13, 37-46, 51-53, 68, 72-83 ----- 3, 14-16, 48-50, 57-60, 67, 69-71, 84
Y --- A	US 2004/0126710 A1 (Hill et al.) 01 July 2004 (01.07.2004), entire document, especially Fig. 7	13 ----- 3, 14-16, 48-50, 57-60, 67, 69-71, 84
Y	US 4,191,609 A (Trokhan) 04 March 1980 (04.03.1980), entire document, especially col. 7	37
Y	US 5,628,876 A (Ayers et al.) 13 May 1997 (13.05.1997), entire document, especially col. 10	38-43
Y --- A	US 2015/0211179 A1 (Alias et al.) 30 July 2015 (30.07.2015), entire document, especially para. [0015-0017]	44-46, 51-53, 80-83 ----- 3, 14-16, 48-50, 57-60, 67, 69-71, 84
Y	US 5,152,874 A (Keller) 06 October 1992 (06.10.1992), entire document, especially Fig. 2 col. 5	68, 72-82

Further documents are listed in the continuation of Box C.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier application or patent but published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 12 April 2017	Date of mailing of the international search report <b>09 JUN 2017</b>
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 17/17705

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2010/0230064 A1 (Eagles et al.) 16 September 2010 (16.09.2010), entire document	1-85
A	US 8,758,569 B2 (Aberg et al.) 24 June 2014 (24.06.2014), entire document	1-85