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(54) Title: FLEXIBLE LAMINATE COMPOSITE FABRIC AND METHOD OF MAKING THE SAME

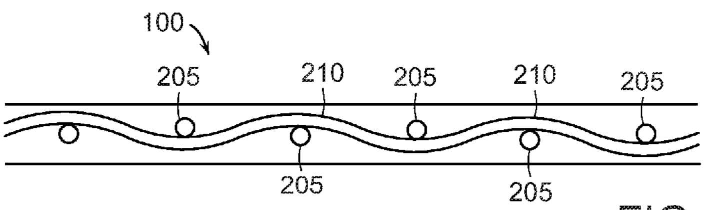

FIG. 1

(57) Abstract: The present invention solves the problems associated with reinforcing a multilayered article of manufacture, particularly a footwear article requiring a particular combination of strength, durability and weigh characteristics without a substantial increase in cost. The composite of the present invention has a lightweight, strong, durable mesh fiber affixed between two lightweight, flexible, strong laminate layers having perforations therethrough for facilitating evaporation of moisture which imparting a high flex fatigue to the article of manufacture.

FLEXIBLE LAMINATE COMPOSITE FABRIC AND METHOD OF MAKING THE SAME

BACKGROUND

1. Field of the Invention

[0001] The present invention relates generally to composite fabric and more particularly to a durable lightweight, flexible, breathable fabric that does not stretch or tear under load conditions, and that comprises sufficient surface area for secured bonding to other fabrics for use in products repeatedly subjected to acute forces.

2. Discussion of Background information

[0002] Composite laminate fabrics, especially those used in footwear as an intermediate support layer, typically lack strength and breathability, and therefore lack structural support and comfort. In all shoes, a thin intermediate support layer called the "doubler" provides structural support for the outer materials and the inner lining materials. Producing a shoe that is comfortable and durable requires that the doubler be breathable, strong and lightweight.

[0003] Reducing the weight of a running shoe, for example, by a single ounce saves a runner from carrying 16 tons of weight over the course of a marathon. Adding strength without adding weight is paramount because of the forces imparted on footwear. Footwear "blow out" is a common mode of failure for high performance footwear, such as soccer shoes. These articles are subjected to extreme lateral forces as the sole of the foot moves off the sole platform in the lateral direction, and these extreme lateral forces lead to catastrophic failure events, such as blowouts. Blowouts account for a large portion of footwear returns, which in turn lead to reduced profits for manufacturers. Footwear support layers therefore need to be flexible and strong for long lasting durability.

[0004] Selecting materials for such doublers requires balancing desired material characteristics with cost effectiveness. The materials must be functional, but not contribute to a substantial increase in cost of the footwear or a reduction in breathability. Some manufactures have addressed this problem with materials having good mechanical strength, but which are often impervious to air and moist vapor movement, thereby rendering the shoe hot and uncomfortable.

[0005] Doubler layers having excellent breathability characteristics, such as fiber meshes, typically lack strength and sufficient surface area for effective attachment to the upper layer and inner lining layer. Strengthening a fiber mesh requires incorporation of large diameter fibers arranged densely. This adds weight and reduces breathability. Incorporating smaller diameter, high performance fibers increases cost. Meshes also present a unique mode of mechanical failure, namely fiber movement under force from a foot, specifically the toes of a foot. The little toe or the first knuckle of the big toe typically force their way through a fiber mesh by pushing the parallel and perpendicular (horizontal axial and vertical axial) yarns out of the way, resulting in a hole or expanded open area in the mesh, and thereby defeating the purpose of the mesh reinforcement.

[0006] Common methods for binding such mesh fibers together at their intersections (i.e. nodes) present additional problems. Soft bonding techniques, such as stitching and incorporating binding fibers at each node impart the mesh with insufficient mechanical strength to withstand load forces. Thermally bonding fibers causes degradation and lessening of yield strength of the fibers, thereby weakening the mesh. Firmer, more permanent bonding techniques, create hard points at the nodes that cause excessive flexural fatigue in the support fiber at the location where the hard, bound node meets the remainder of the support fiber.

[0007] A need therefore exists for a strong, lightweight, breathable composite material that will not delaminate from other layers of footwear construction under application of force and that has a high flex fatigue and tensile strength to prevent failure under repeated, acute applications of force.

SUMMARY OF THE INVENTION

[0008] The present invention solves the problems associated with reinforcing a multilayered article of manufacture, particularly a footwear article requiring a particular combination of strength, durability and weigh characteristics without a substantial increase in cost. The composite of the present invention has a lightweight, strong, durable mesh fiber affixed between two lightweight, flexible, strong laminate layers having perforations therethrough for facilitating evaporation of moisture.

[0009] One embodiment of the lightweight, breathable reinforcing flexible laminate composite of the present invention comprises a top layer of biaxially-oriented film and a bottom layer of biaxially-oriented film affixed to the top layer of biaxially-oriented film. Fixedly disposed between the top layer of biaxially-oriented film and a bottom layer of biaxially-oriented film is a mesh layer of fibers aligned in parallel and interwoven rows and columns in a grid formation. The mesh layer of fibers is immobilized between the top layer and bottom layer of biaxially-oriented film. In one embodiment, the top layer and bottom layer of biaxially-oriented film form an airtight seal around the mesh layer of fibers.

[0010] In one embodiment, the lightweight, breathable reinforcing flexible laminate composite of the present invention comprises a plurality of perforations extending through the top layer of biaxially-oriented film and bottom layer of biaxially-oriented film and disposed in between the fibers of the immobilized mesh layer of fibers. The perforations therefore are formed through top and bottom layer of biaxially-oriented film at the interstices between the fibers laid out in grid formation to form the mesh grid.

[0011] The present invention also comprises a method of making a lightweight, breathable reinforcing flexible laminate composite fabric. In one embodiment, the method comprises providing a first layer of biaxially-oriented film, providing a second layer of biaxially-oriented film for affixation to the first layer of biaxially-oriented film. The method also comprises applying an adhesive to at least the first layer of biaxially-oriented film and laminating onto the adhesive of the first layer of biaxially-oriented film a mesh layer of fibers fixedly disposed in a grid formation.

[0012] The method further comprises applying the second layer of biaxially-oriented film onto the mesh layer of fibers and first layer of biaxially-oriented film such that the mesh layer of fibers is immobilized between the first layer and second layer of biaxially-oriented film form an airtight seal around the mesh layer of fibers. The lightweight breathable reinforcing flexible laminate composite fabric is completed by forming a plurality of perforations extending through the first layer of biaxially-oriented film and second layer of biaxially-oriented film without severing any of the fibers of the mesh layer of fibers.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] One will better understand these and other features, aspects, and advantages of the present invention following a review of the description, appended claims, and accompanying drawings:

[0014] FIG. 1 is a cross-sectional side view of one embodiment of the lightweight, breathable reinforcing flexible laminate composite fabric of the present invention prior to affixation of the composite layers.

[0015] FIG. 2 is a top view of one embodiment of the mesh fiber layer of the lightweight, breathable reinforcing flexible laminate composite fabric of the present invention.

[0016] FIG. 3 is a top view of one embodiment of a biaxially-oriented film of the lightweight, breathable reinforcing flexible laminate composite fabric of the present invention.

[0017] FIG. 4A is a cross-sectional side view of one embodiment of the lightweight, breathable reinforcing flexible laminate composite fabric of the present invention following affixation of the composite layers.

[0018] FIG. 4B is a top view of one embodiment of the lightweight, breathable reinforcing flexible laminate composite fabric of the present invention following affixation of the composite layers.

[0019] FIG. 5 is a partial top view of a non-reinforced composite fabric subjected to the application of force.

[0020] FIG. 6A is a top view of one embodiment of a biaxially-oriented film of the lightweight, breathable reinforcing flexible laminate composite fabric of the present invention.

[0021] FIG. 6B is a top view of one embodiment of a biaxially-oriented film of the lightweight, breathable reinforcing flexible laminate composite fabric of the present invention.

[0022] FIG. 7 is a top view of one embodiment of a biaxially-oriented film of the lightweight, breathable reinforcing flexible laminate composite fabric of the present invention.

[0023] FIG. 8 is a top view of one embodiment of a biaxially-oriented film of the lightweight, breathable reinforcing flexible laminate composite fabric of the present invention.

DETAILED DESCRIPTION

[0024] The present invention solves the problems associated with standard footwear support layers, i.e. doublers. The present invention provides a breathable, lightweight, sturdy, durable, cost effective reinforcing flexible laminate composite fabric (having sufficient surface area for permanent attachment to both the upper layer and inner lining of a shoe. The present invention thus provides numerous benefits to the user, as described more fully below with reference to the drawings.

[0025] As depicted in the embodiment FIG. 1, the present invention is a breathable, lightweight, sturdy, durable, cost effective reinforcing flexible laminate composite fabric (hereafter, "composite fabric") 100 comprising a top layer of film 105a, a bottom layer of film 105b and a mesh layer of fibers (hereafter "mesh layer") 200 fixedly disposed in a grid formation therebetween. The mesh layer 200 is immobilized between the top layer of film 105a and bottom layer of film 105b. The top layer of film 105a and bottom layer of film 105b compress and permanently attach to form an airtight seal around the mesh layer 200, thereby preventing migration or movement of any of the fibers 205, 210 forming the mesh layer 200. FIG. 5 depicts a portion of one embodiment of the composite fabric 100 of the present invention during the application of force in a targeted area 500, such as application of force by a toe abutting the composite fabric installed in an athletic shoe. Immobilizing the fibers 205, 210 of the mesh layer 200 prevents migration from the position indicated by A to the position indicated by B, which would result in a zone of weakness in the composite fabric 100 and potentially lead to catastrophic tearing or rupture. In one embodiment, the composite fabric weighs 3oz or less per square yard and exhibits double the strength characteristic at same weight of a standard doubler layer or the same strength characteristic at two thirds the weight of standard doubler fabric.

[0026] As indicated in the cross sectional depiction of FIG. 4A, in a fully assembled state, one embodiment of the present invention further comprises an adhesive 110 applied between the top layer of film 105a and bottom layer of film 105b. In one embodiment, the adhesive 100 is applied fully and uniformly across all of one or both of the top layer of film 105a and bottom layer of film 105b and in another embodiment, the adhesive 110 may be applied sporadically and/or as a supplement to other affixation techniques, such as but not limited to thermal bonding, of the top layer of film 105a to the bottom layer of film 105b. Preferably, the adhesive 110 is applied fully and uniformly such the mesh layer 200 is affixed and immobilized across the entire composite fabric 100.

[0027] Turning now to the embodiment of FIG. 3, a layer of film 105, which could become either the top layer of film 105a or the bottom layer of film 105b, comprises a plurality of perforations 300 therethrough. Preferably, the top layer of film 105a and the bottom layer of film 105b are of identical dimensions with the plurality of perforations 300 positioned at identical locations so that they align during lamination of the composite fabric 100 without leaving any tacky adhesive exposed. Pre-manufacturing the plurality of perforations 300 in a layer of film 105, prevents accidentally puncturing and weakening the mesh layer 200. In another embodiment, however, the plurality of perforations 300 may be formed in the completed composite fabric 100 following lamination of the top layer of film 105a, mesh layer 200 and bottom layer of film 105b. The plurality of perforations 300 are formed carefully and without severing the fibers 205, 210 forming the mesh layer 200.

[0028] FIGS. 4A and 4B depict a plurality of perforations 300 formed through the top layer of film 105a and bottom layer of film 105b such that the completed assembly of the composite fabric 100 comprises a plurality of perforations 300 extending through the top layer of film 105a and bottom layer of film 105b and disposed in between the fibers 205, 210 in the grid formation of the mesh layer 200. In either embodiment of formation of the plurality of perforations 300, the plurality of perforations 300 are aligned so as not to overlap or expose the mesh layer 200, which remains immobilized between the top layer of film 105a and bottom layer of film 105b and protected from wear and tear, thereby reliably adding strength to the composite fabric 100.

[0029] Turning now to the particulars of the mesh layer 200, in one embodiment, the mesh layer 200 comprises interwoven horizontal axial fibers 205 and vertical axial fibers 210 crossing over one another at a 90 degree angle. In another embodiment, the vertical axial fibers 210 and horizontal axial fibers 205 are not horizontal and vertical and instead cross over one another at a 45 degree angle. In other embodiments, the angles between the horizontal axial fibers 205 and vertical axial fibers 210 are not horizontal and vertical and instead cross over one another at an angle between 30-85 degree. In another embodiment, the mesh layer 200 comprises horizontal and vertical rows of fibers laid atop one another without interweaving the same. In one embodiment, the mesh layer of fibers 200 is interwoven and the fibers 205, 210 are bonded at their nodes 215, the locations of intersection. In another embodiment, the mesh layer of fibers is not interwoven, but are laid across one another and the fibers are bonded together at their nodes 215. Preferably, the fibers 205, 210 are interwoven such that they are firmly secured relative to one another and restricted from movement.

[0030] Returning now to the affixation of the horizontal axial fibers 205 and vertical axial fibers 210 at their nodes 215, bonding the fibers 205, 210 of the mesh layer 200 at the nodes 215 enables the mesh layer 200 to maintain constant overall dimensions under the application of force. Bonding the nodes 215 enables the fibers 205, 210 also to maintain stability and withstand localized movement of fibers 205, 210 under acute and often repeated applications of force. The nodes 215 may be secured by any number of means, such as, for example, mechanical ties (such as, but not limited to, those applied by a stitch bonding machine), binder fibers, ultrasonic welds, adhesive bond, or thermal bond. Preferably, the nodes 215 are mechanically bonded by tying them with separate piece of fiber without adding thickness to the mesh layer 200 and preventing a tightly formed seal of the top layer of film 105a and bottom layer of film 105b around the mesh layer 200. Having protrusions at the nodes 215 would prevent formation of a compressed composition fabric 100 with a securely retrained mesh layer 200 that resists movement under applications of force. The mechanical means of securing the nodes 215, for example, tying the nodes with separate pieces of fiber, prevents degrading the structural strength of the individual fibers 205, 210 and therefore the structural strength of the mesh layer 200 overall. Thermal bonding techniques, for example, cause degradation in the strength of fibers and weakens a mesh formed thereof.

[0031] Forming a structurally strong, flexible, lightweight mesh 200 requires selecting the right fiber material or combination of fiber materials that achieve the desired balance of high performance and low cost characteristics. In one embodiment, the horizontal axial fibers and/or vertical axial fibers are bi-component fibers. The horizontal axial fibers and vertical axial fibers may be the same material, different material, or combinations of the same and different materials. For example, as indicated in FIG. 2, the horizontal axial fibers 205 and vertical axial fibers 210 may be the same material and dimensioned to the same thickness, or diameter, except that the vertical axial fibers 210 further comprise sporadically spaced alternate fibers 212 of material having superior tensile strength than that of the horizontal axial fibers 205 and vertical axial fibers 210. In one embodiment, the alternate fibers 212 run vertically and/or horizontally. In another embodiment, the alternate fibers are biaxially-oriented (i.e. 45 degree angle) relative to the horizontal axial fibers 205 and vertical axial fibers 210 In one embodiment, the alternate fibers 212 may be of a different thickness or diameter, but preferably, the alternate fibers 210 are of similar or identical dimensions to those of the vertical axial fibers 210 such that the mesh layer 200 is of uniform overall thickness. Producing a mesh of uniform overall thickness further improves the production of a composite fabric 100 having a tightly secured mesh fabric 200 immobilized therein without any points of incongruity that could lead to delamination of the composite fabric 100 and/or movement of the fibers 205, 210, 212 of the mesh layer 200.

[0032] In one embodiment, some or all of the horizontal axial fibers 205, vertical axial fibers 210 and/or alternate fibers 212 may be a lightweight, high tensile strength, low elongation reinforcing fiber. In another embodiment only the alternate fibers 212 are manufactured from a lightweight, high tensile strength, low elongation reinforcing fiber. Typically, such fiber materials produce excellent performance characteristics, but are more costly than other types of fibers. Therefore, interspersing such material between the other fiber materials in the mesh layer 200 increases overall performance exponentially with out adding significant cost to a final product. The alternate fibers 212 may be manufactured from materials such as, but not limited to, high tenacity yarn, ultra high molecular weight polyethylene (UHMWPE), polyethylene naphthalate (PEN), aramid polymer, carbon fiber or fiberglass. Preferably, the alternate fibers are manufactured from a UHMWPE material, such as Spectra® manufactured by Honeywell®. In one embodiment the horizontal axial fibers 205, vertical axial fibers 210 and/or alternate fibers 212 have a denier ranging from 100 to 3800 and an ultimate tensile strength ranging between 5 and 50 grams per denier. In one embodiment, the horizontal axial fibers 205, vertical axial fibers 210 and/or alternate fibers 212 are Spectra® have an ultimate tensile strength ranging between 30 and 39 grams per denier. In one embodiment, the horizontal axial fibers 205, vertical axial fibers 210 and/or alternate fibers 212 are made of high tenacity yarn having an ultimate tensile strength equal to or greater than 6 grams per denier. In one embodiment, the horizontal axial fibers 205, vertical axial fibers 210 and/or alternate fibers 212 have a tensile modulus of at least 900 grams per denier. In one embodiment, the horizontal axial fibers 205, vertical axial fibers 210 and/or alternate fibers 212 have an elongation at break of less than 5 percent.

[0033] In a preferred embodiment, at least the alternate fibers 212 interspersed within the horizontal axial fibers 205 and/or vertical axial fibers 210, provide all of these performance characteristics. In a preferred embodiment, the alternate fibers 212 have a denier between 100-4800, an ultimate tensile strength of greater than 6 grams per denier for the horizontal axial fibers 205 and vertical axial fibers 210, an ultimate tensile strength between 30 to 39 for Spectra® fibers comprising the alternate fibers 212, a tensile modulus of at least 900 grams per denier for the alternate fiber 212 and an elongation at break of less than 5 percent for the alternate fiber 212. Preferably, at least the alternate fibers 212 have a high flex fatigue and high breaking strength, for example, 9 pounds for a denier of 100. Additionally, in a preferred embodiment, at least the alternate fibers, and preferably the horizontal axial fibers 204 and vertical axial fibers 210 as well, have a low moisture absorption percentage, for example, less than 1% and more preferably, less than 0.5%. Preventing moisture regain and providing a strong, flexible composite fabric 100 that does not stretch or yield catastrophically under acute, repetitive applications of force, such as those associated with a high performance athletic shoe, enables the creation of a sturdy, flexible comfortable final product with a long usage lifespan. In the example of athletic footwear, this could reduce the number of returns for catastrophic, untimely failure and thereby increase revenue and marketing appeal for a manufacturer.

[0034] Creating a composite fabric 100 having superior strength, comfort and flexibility characteristics requires not only selecting, arranging and affixing the fibers 205, 210, 212 of the mesh layer 200, but also combining the performance characteristics of the mesh layer 200 with a particularly dimensioned and strengthened film layer 105 comprising the top layer of film 105a and bottom layer of film 105b. In one embodiment, the film layer 105 is manufactured from an inelastic, flexible plastic film having high tensile strength and high burst strength resistance as measured by a Mullen burst test, or any burst test designed to ensure that film layer 105 remains intact and that the fibers 205, 210, 212 of the mesh layer 200 remain in the designed mesh configuration under severe, focused load imparted on the composite fabric 100. In a preferred embodiment, the fiber film 105 is a biaxially-oriented film 105, wherein a film has been drawn in the machine direction to stretch the fibers comprising the film, reducing their diameters and aligning the fibers to form covalent bonds. Such a biaxially-oriented film 105 therefore is stronger than an extruded plastic film and relatively very thin, such the strength to weight ratio increases greatly as compared to standard plastic films.

[0035] In one embodiment, the top layer of film 105a and bottom layer of film 105b are manufactured from the same material and in another embodiment, the top layer of film 105a and bottom layer of film 105b are manufactured from different materials having similar performance characteristics. Preferably, the top layer of film 105a and bottom layer of film 105b are manufactured from the same material to ensure a reliable composite fabric 100 reliably exhibiting desired performance characteristics. In one embodiment, the biaxially-oriented film 105 comprising the top layer of film 105a and bottom layer of film 105b is biaxially-oriented polyethylene terephthalate (BOPET). In one embodiment, the biaxially-oriented film 105 comprising the top layer of film 105a and bottom layer of film 105b is biaxially-oriented polypropylene (BOPP). In one embodiment, the biaxially-oriented film 105 comprising the top layer of film 105a and bottom layer of film 105b is biaxially-oriented polyamid (BOPA). In a preferred embodiment, the top layer of film 105a and bottom layer of film 105b are manufactured from BOPET and have a tensile strength in the machine direction of 5 to 50,00 pounds, and preferably at least 40,500 pounds, and a tensile strength of 5 to 50,000 pounds, and preferably at least 36,250, pounds in the cross machine direction. In one embodiment, the thickness of each of the top layer of film 105a and bottom layer of film 105b ranges from 3 microns to 15 microns. In a preferred embodiment, the thickness of each of the top layer of film 105a and bottom layer of film 105b is no greater than 9 microns. In this embodiment, combined with the preferred embodiment of the mesh layer, the composite fabric 100 has a burst strength of greater than 1000 pounds.

[0036] Each of the top layer of film 105a and bottom layer of film 105b further comprises a plurality of perforations 300 therethrough, which can be any shape, but preferably is a rounded shape having no sharp corners at which tearing would propagate under application of force. For example, the plurality of perforations 300 may be evenly spaced round perforations 300 as shown in FIGS. 3 through 5, elliptical perforations 315, 320 as shown in FIGS. 6A and 6B, or star shaped perforations 330, as shown in FIG. 7. In one embodiment, the plurality of perforations 300 are pre-formed through each of the top layer of film 105a and bottom layer of film 105b. In an embodiment of the composite fabric 100 having adhesive 110 therein affixing the top layer of film 105a to the bottom layer of film 105b such that the mesh layer 200 is immobilized there between, pre-forming the plurality of perforations 300 eliminates any adhesive buildup on cutting implements used to form the plurality of perforations 300, thereby increasing production efficiency by decreasing time associated with continuously cleaning cutting surfaces to maintain accuracy and precision of cuts.

[0037] Preferably, the plurality of perforations 300 formed through the top layer of film 105a are positioned such that their center 302 points align with the center points 302 of the plurality of perforations 300 formed through the bottom layer of film 105b. In another embodiment, depicted in FIGS. 6A and 6B, the plurality of elliptical perforations 315 formed in a top layer of film 105b are oriented with vertical longitudinal axes 312 and the plurality of elliptical perforations 320 formed in a bottom layer of film 105b are oriented with horizontal longitudinal axes 322 such that when laminated to form the composite fabric 100, a percentage of overlap occurs such that the composite fabric 100 comprises at least 10% perforation therethrough. Similar embodiments comprise offset or randomly placed perforations, such as the offset star shaped perforations 330 of FIG. 7 and randomly formed circular perforations 340 of FIG. 8. Offset and random placement of the plurality of perforations 300, 310, 320, 330, 340 may facilitate manufacturing processes, thereby improving process efficiency and reducing production costs.

[0038] Preferably, the plurality perforations 300 are formed in the composite fabric 100 after the lamination of the top layer of film 105a, mesh layer 200 and bottom layer of film 105b. Forming the plurality of perforations after laminating the top layer of film 105a, mesh layer 200 and bottom layer of film 105b prevents exposure of the mesh layer and/or adhesive 110. Preventing exposure of the mesh layer 200 prevents snagging, cutting, and general wear and tear of the mesh layer 200 and keeping the adhesive unexposed prevents creating a tacky composite fabric 100 that is difficult to handle during the manufacturing process. Forming a plurality of perforations 300 following assembly of the composite fabric 100 requires precisely aligning the formation tool, a punch or laser for example, and placing each of the plurality of perforations 300 through only the top layer of film 105a and bottom layer of film 105b without piercing the mesh layer 200.

[0039] Another major consideration in forming the plurality of perforations 300 involves selecting size and quantity such that a certain percentage of film surface area 305 remains available for permanent attachment to one or more articles of manufacture, such as an "upper" element and inner lining element of a shoe. The fibers 205, 210, 212 of the mesh layer 200 are spaced apart between one thirty-second (1/32) to one half (1/2) of an inch in both the horizontal and vertical directions of the grid formation and each of the plurality of perforations 300 is between one sixty-fourth (1/64) of an inch and one eighth (1/8) of an inch at its largest dimension. In one embodiment, for example, the fibers 205, 210, 212 of the mesh layer 200 are spaced apart at least an eighth (1/8) of an inch in both the horizontal and vertical directions of the grid formation and each of the plurality of perforations 300 is one sixteenth (1/16) of an inch at its largest dimension. In another embodiment, for example, the fibers 205, 210, 212 of the mesh layer 200 are spaced apart at least a quarter (1/4) of an inch in both the horizontal and vertical directions of the grid formation and each of the plurality of perforations 300 is three sixteenths (3/16) of an inch at its largest dimension (e.g. a diameter of a circular perforation). The spacing between axial fibers 205, 210, 212 determines not only the strength characteristics of the fibers selected for incorporation into the mesh layer 200, but also the largest dimension of the plurality of perforations 300. As indicated in FIG. 4B, the ratio of A1/A2 is determined by the amount of bonding distance D required to prevent a fiber 205, 210, 212 from sliding out of place, wherein A1 represents the area removed by the perforation 300 within one square of the grid of the mesh layer 200 and A2 represents the area of remaining biaxially-oriented film situated between a perforation 300 and the fibers 205, 210, 212 boxing in that particular perforation 300. Changing the spacing between axial fibers 205, 210, 212 in the mesh layer 200 therefore changes amount of remaining biaxially-oriented film required to prevent the fibers from moving under load. Accordingly the spacing between axial fibers 205, 210, 212 in the mesh layer 200 determines the allowable size of the plurality of perforations 300 punched through the bonded top and bottom layers of biaxially-oriented film 105a, 105b.

[0040] In one embodiment, the plurality of perforations 300 eliminate between 25 and 75 percent of the film surface area 305, and in a preferred embodiment the plurality of perforations 300 remove 40 to 50 percent of the film surface area 305. In yet another embodiment, the plurality of perforations remove 45 percent of the film surface area 305, leaving 55 percent of the film surface area 305 intact and available for attachment to another element, such as a shoe upper. Removing approximately half of the top layer of film 105a and half of the bottom layer of film 105b to create the plurality of perforations 300 through the composite fabric 100 significantly increases breathability and vapor disposition, making the composite fabric 100 comfortable to the wearer, especially in footwear applications in which an active foot heats up and perspires.

[0041] Additionally, by maintaining approximately half of the film surface area 305 intact, the strong, flexible composite fabric 100 retains all of the strength and performance characteristics of the combined, laminated constituent materials while having a reduced weight and still presenting sufficient surface area 305 for permanent, secure attachment to other product components from which the composite fabric 100 will not delaminate under repeated applications of force. For example, in one embodiment, an adhesive applied across the composite fabric 100 permanently affixes the composite fabric 100 to a shoe upper without impeding permeability through the plurality of perforations. Such adhesive affixation ensures that the composite fabric does not delaminate from the shoe upper, which maybe manufactured from a material such as leather, from which fibers typically delaminate.

[0042] The present invention further comprises a method of making the lightweight, breathable reinforcing flexible laminate composite fabric. The method comprises providing a first layer of biaxially-oriented film 105a, providing a second layer of biaxially-oriented film 105b for affixation to the first layer of biaxially-oriented film 105a and applying an adhesive 110 to at least the first layer of biaxially-oriented film 105a. In one embodiment, the adhesive 110 is applied uniformly across all of one surface of the first layer of biaxially-oriented film 105a. In another embodiment, adhesive may be applied to the first layer of biaxially-oriented film 105a and second layer of biaxially-oriented film 105b.

[0043] In one embodiment, the method further comprises laminating onto the adhesive 110 of the first layer of biaxially-oriented film 105a a mesh layer of fibers 200 fixedly disposed in a grid formation and then applying the second layer of biaxially-oriented film 105b onto the mesh layer of fibers 200 and first layer of biaxially-oriented film 105a such that the mesh layer of fibers 200 is immobilized between the first layer of biaxially-oriented film 105a and second layer of biaxially-oriented film 105b form an airtight seal around the mesh layer of fibers. Formation of this airtight seal prevents the fibers of the mesh layer of fibers 200 from moving under application of force.

[0044] In one embodiment, the method further comprises forming a plurality of perforations extending through the first layer of biaxially-oriented film affixed to the second layer of biaxially-oriented film without severing any of the fibers of the mesh layer of fibers. In this embodiment, the assembled composite fabric 100 may be, for example, placed on a tenter frame having pins that hold the composite fabric 100 taught such that an automated optical system locates the mesh layer 200 and enables high torque microcontrollers to punch the plurality of perforations 300 accurately therebetween without severing any portion of the mesh layer 200. In another embodiment, the plurality of perforations 300 may be pre-formed in the top layer of biaxially-oriented film 105a and bottom layer of biaxially-oriented film 105b and an optical system may be used to align the centers of the plurality of perforations 300 in the top layer of biaxially-oriented film 105a and with the plurality of perforations 300 in the bottom layer of biaxially-oriented film 105b such that the assembled composite fabric 100 has a plurality of perforations 300 therethrough without leaving exposed any adhesive 110.

[0045] In another embodiment, the method comprises affixing the top layer of biaxially-oriented film 105a and bottom layer of biaxially-oriented film 105b using a thermal means, such as melting, reflow or heat pressing, such that the mesh layer 200 is immobilized therebetween. In all embodiments of the method of manufacture of the composite fabric 100, the mesh layer 200 is immobilized such that none of the fibers 205, 210, 212 therein spread apart under the application of force, such as the pointed and acute repetitive application of force by one or more toes in a footwear application of the present invention. Although the composite fabric 100 is described throughout with reference to application in a footwear product, other applications of the present invention are contemplated, particularly applications requiring strength, flexibility, breathability and resistance to stretching or yielding under acute, repetitive applications of force. Such applications may include construction of various athletic devices or articles of clothing, for example.

[0046] It is noted that the foregoing examples have been provided merely for the purpose of explanation and are in no way to be construed as limiting of the present invention. While the present invention has been described with reference to an exemplary embodiment, it is understood that the words, which have been used herein, are words of description and illustration, rather than words of limitation. Changes may be made, within the purview of the appended claims, as presently stated and as amended, without departing from the scope and spirit of the present invention in its aspects. Although the present invention has been described herein with reference to particular means, materials and embodiments, the present invention is not intended to be limited to the particulars disclosed herein; rather, the present invention extends to all functionally equivalent structures, methods and uses, such as are within the scope of the appended claims.

I claim:

1) A lightweight, breathable reinforcing flexible laminate composite fabric comprising:
   a) a top layer of biaxially-oriented film;
   b) a bottom layer of biaxially-oriented film affixed to the top layer of biaxially-oriented film;
   c) a mesh layer of fibers fixedly disposed in a grid formation between the top layer and bottom layer of biaxially-oriented film such that the mesh layer of fibers is immobilized and such that the top layer and bottom layer of biaxially-oriented film form an airtight seal around the mesh layer of fibers; and
   d) a plurality of perforations extending through the top layer of biaxially-oriented film and bottom layer of biaxially-oriented film and disposed in between the fibers of the immobilized mesh layer of fibers.
2) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 1, wherein the mesh layer of fibers is woven into the grid formation such that the mesh layer contains a plurality of crisscrossed axial fibers oriented at 90 degrees to one another. The lightweight, breathable reinforcing flexible laminate composite fabric of claim 2, wherein the plurality of crisscrossed axial fibers are made of different materials.
3) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 1, wherein the fibers disposed in the grid formation are bonded together at their junctions so the mesh layer of fibers maintains constant dimensions under application of force.
4) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 6, wherein the junctions are mechanically tied by a stitchbonding machine.
5) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 6, wherein the junctions are secured with a binder fiber.
6) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 6, wherein the junctions are ultrasonically welded.
7) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 6, wherein the junctions are thermally bonded.
8) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 1, wherein the fibers of the mesh layer of fibers are made of ultra high molecular weight polyethylene.

9) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 1, wherein the fibers of the mesh layer of fibers are made high tenacity yarns of 6g per denier or higher.

10) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 1, wherein the fibers of the mesh layer of fibers are made of polyethylene naphthalate (PEN).

11) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 1, wherein the fibers of the mesh layer of fibers are made of an aramid polymer.

12) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 1, wherein the fibers of the mesh layer of fibers are made of carbon fiber.

13) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 1, wherein the fibers of the mesh layer of fibers are made of fiberglass.

14) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 1, wherein the fibers of the mesh layer of fibers have a denier ranging from 100 to 4800.

15) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 1, wherein the fibers of the mesh layer of fibers have an ultimate tensile strength between 5 and 50 grams per denier.

16) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 15, wherein the fibers of the mesh layer of fibers have an ultimate tensile strength between 30 and 39 grams per denier.

17) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 1, wherein the ultimate tensile strength of the fibers of the mesh layer of fibers is equal to or greater than 6 grams per denier.

18) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 1, wherein the fibers of the mesh layer of fibers have tensile modulus of at least 900 grams per denier.

19) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 1, wherein the biaxially-oriented film is biaxially-oriented polyethylene terephthalate (BOPET).

20) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 1, wherein the biaxially-oriented film is biaxially-oriented polypropylene (BOPP).

21) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 1, wherein the biaxially-oriented film is biaxially-oriented polyamid (BOPA).

22) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 1, wherein the top layer of biaxially-oriented film has a tensile strength of at 5 to 50,000 pounds in the machine direction.

23) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 22, wherein the top layer of biaxially-oriented film has a tensile strength of 40,500 pounds in the machine direction.

24) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 1, wherein the top layer of biaxially-oriented film has a tensile strength of at least 5 to 50,000 pounds in the cross machine direction.

25) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 24, wherein the top layer of biaxially-oriented film has a tensile strength of at least 36,250 pounds in the cross machine direction.

26) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 1, wherein the bottom layer of biaxially-oriented film has a tensile strength of at least 40,500 pounds in the machine direction.

27) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 1, wherein the bottom layer of biaxially-oriented film has a tensile strength of at least 36,2500 pounds in the cross machine direction.

28) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 1, wherein the thickness of the top layer of biaxially-oriented film and bottom layer of biaxially-oriented film is 3-15 microns.

29) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 28, wherein the thickness of the top layer of biaxially-oriented film and bottom layer of biaxially-oriented film is no greater than 9 microns.

30) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 1, wherein the fibers of the mesh layer of fibers are spaced apart in a range of 1/32 to ½ inch, in both directions of the grid formation.

31) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 30, wherein the fibers of the mesh layer of fibers are spaced apart in a range of at least an eighth of an inch.

32) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 28, wherein each of the plurality of perforations is 1/64 to 1/8 inch at its largest dimension.

33) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 32, wherein each of the plurality of perforations is 1/16 inch at its largest dimension.

34) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 1, wherein the fibers of the mesh layer of fibers are spaced apart at least a quarter of an inch in both directions of the grid formation.

35) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 34, wherein each of the plurality of perforations is 3/16 inch at its largest dimension.

36) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 1, wherein the plurality of perforations remove between 25 and 75 percent of the surface area of the fabric.

37) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 32, wherein the plurality of perforations remove 50 percent of the surface area of the fabric.

38) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 1, wherein at least one of the top layer of biaxially-oriented film and bottom layer of biaxially-oriented film is coated with adhesive for immobilizing the mesh layer of fibers therebetween.

39) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 34, wherein the adhesive is applied uniformly and completely across the entire surface of the at least one layer of the top layer of biaxially-oriented film and bottom layer of biaxially-oriented film.

40) The lightweight, breathable reinforcing flexible laminate composite fabric of claim 1, wherein the top layer of biaxially-oriented film and bottom layer of biaxially-oriented film are thermally bonded for immobilizing the mesh layer of fibers therebetween.

41) A method of making a lightweight, breathable reinforcing flexible laminate composite fabric, comprising:

a) providing a first layer of biaxially-oriented film;
b) providing a second layer of biaxially-oriented film for affixation to the first layer of biaxially-oriented film;
c) applying an adhesive to at least the first layer of biaxially-oriented film;
d) laminating onto the adhesive of the first layer of biaxially-oriented film a mesh layer of fibers fixedly disposed in a grid formation;
e) applying the second layer of biaxially-oriented film onto the mesh layer of fibers and first layer of biaxially-oriented filmsuch that the mesh layer of fibers is immobilized between the first layer and second layer of biaxially-oriented film; and

f) forming a plurality of perforations extending through the first layer of biaxially-oriented film and second layer of biaxially-oriented film without severing any of the fibers of the mesh layer of fibers.

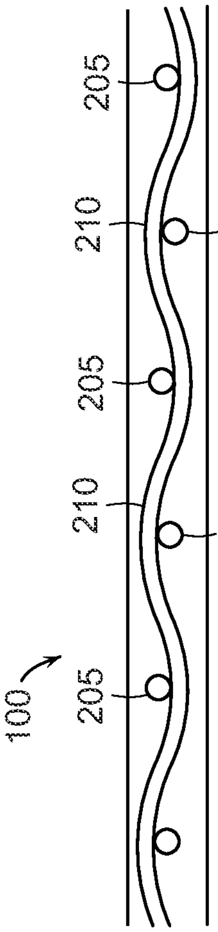

FIG. 1

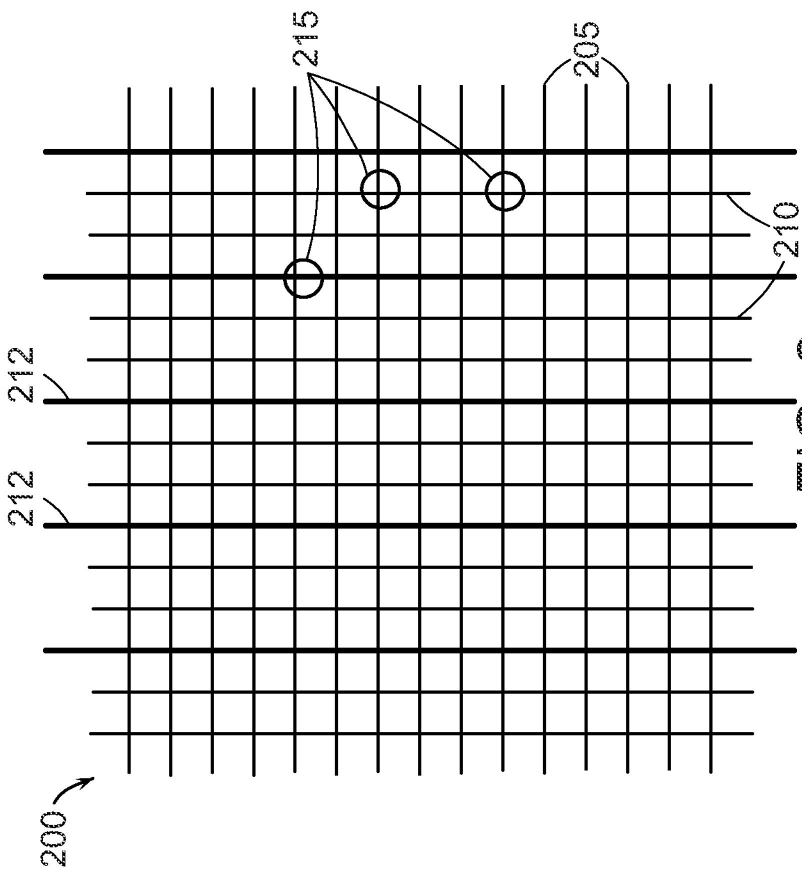

FIG. 2

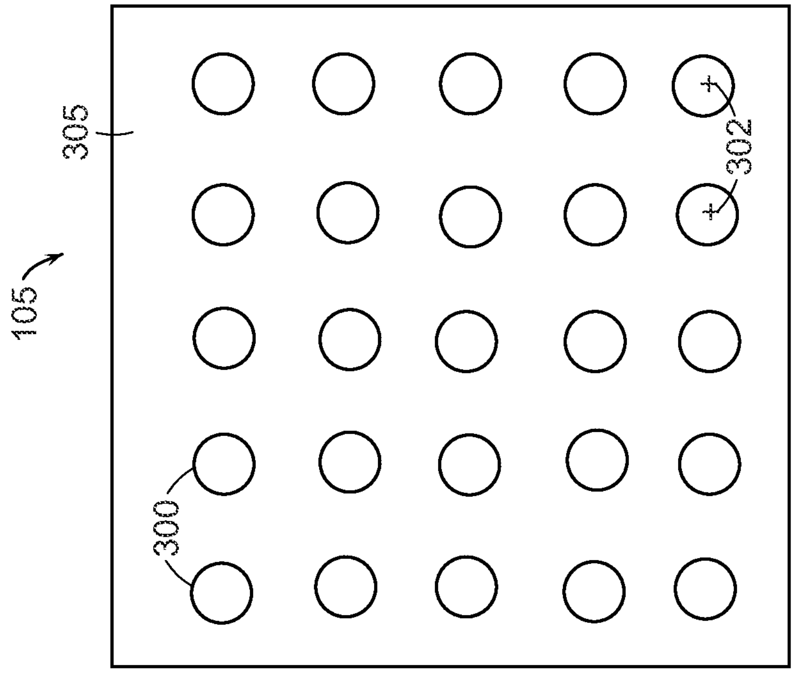

FIG. 3

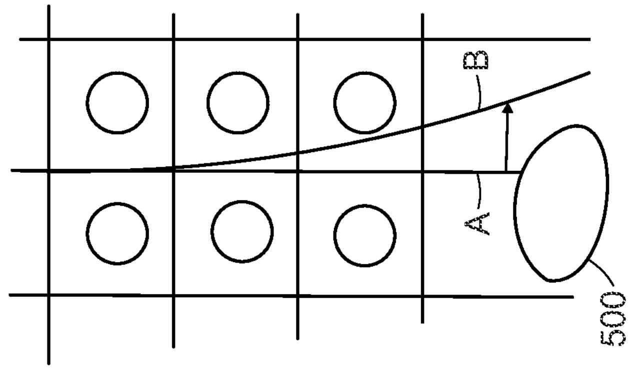

FIG. 5

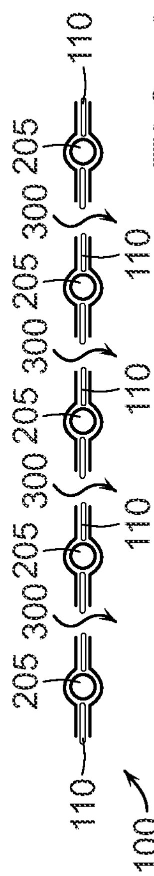

FIG. 4A

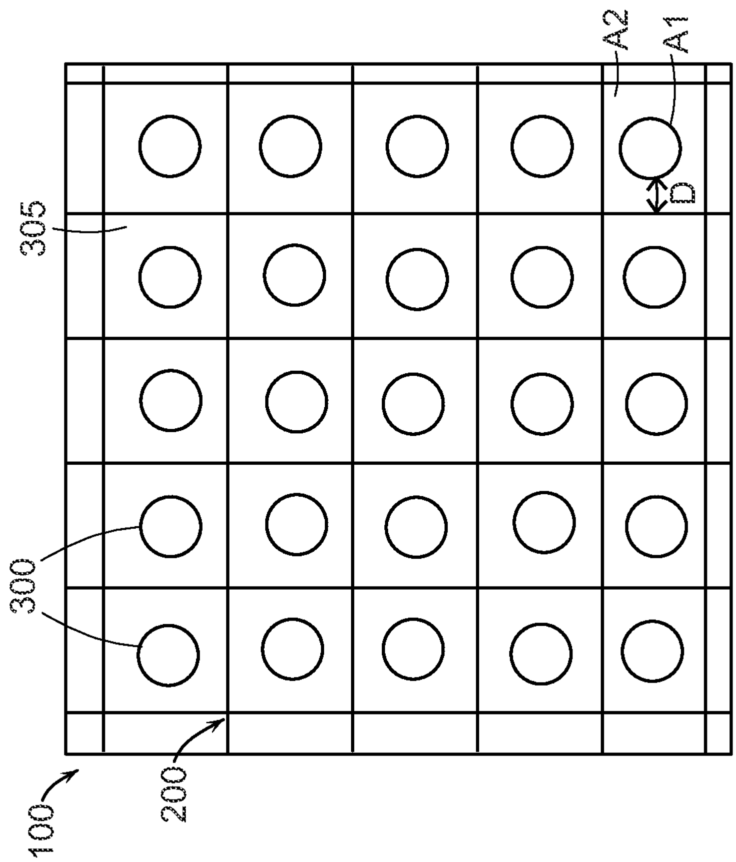

FIG. 4B

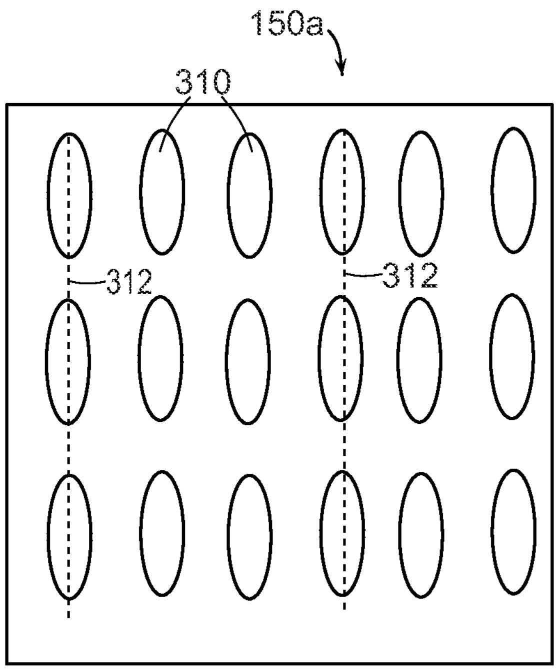

FIG. 6A

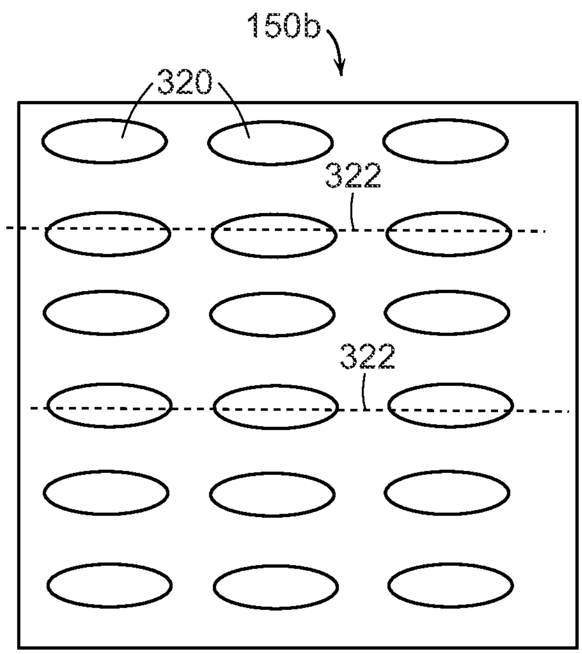

FIG. 6B

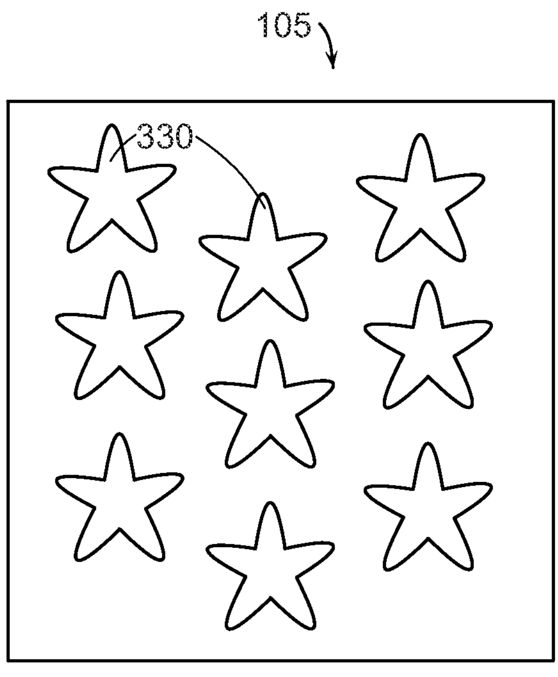

FIG. 7

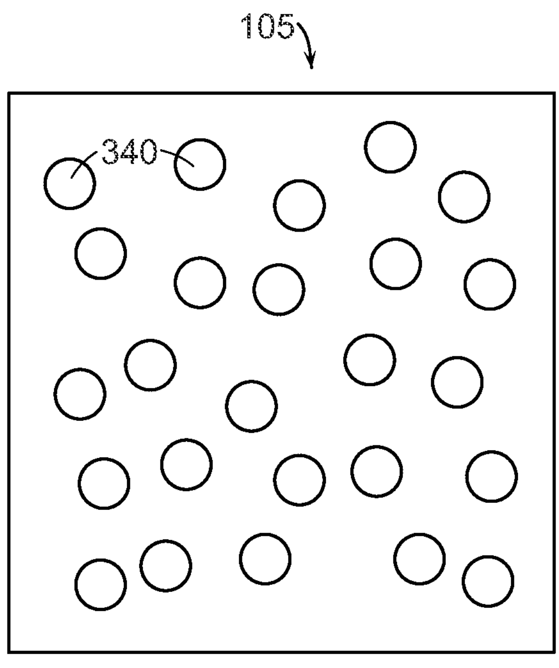

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 12/48100

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - B32B 3/00 (2012.1)
USPC - 156/290 and 156/553
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)
USPC: 156/290, 156/553
IPC:B232B 3/00 (2012.1)

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
DERWENT File 351 Dialog Classic, PATFT USPTO, Google Scholar
Search Terms: biaxially oriented, fabric, mesh, fiber, perforate, punch, laminate, film

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 6,033,509 A (Miyamoto et al.) 07 March 2000 (07.03.2000) Figs. 3A and 3B; col 7, ln 19-40; col 7, ln 37-40; col 3, ln 64-67	1-2, 2a, 3-41
Y	US 4,653,640 A (Akao) 31 March 1987 (31.03.1987) Figs 1-2; Fig 16; col 2, ln 21-23; col 4, ln 66 to col 5, ln 14; col 5, ln 3-14;col 5, ln 12-14; col 9, 39-41; col 9, 50-53; col 12, ln 3-20; col 13, ln 16-18; col 13, ln 37-41; col 14, ln 38-42; col 14, ln 53-59; col 15, ln 66-68	1-2, 2a, 3-41
Y	US 4,167,429 A (Ackley) 11 September 1979 (11.09.1979) col2, ln 10-38	2a
Y	US 2005/0003141 A1 (Zafiroglu) 06 Jan 2005 (06.01.2005) para [0080, 0083-0084]	4
Y	US 4,552,795 A (Hansen et al.) 12 November 1985 (12.11.1985) col 4, ln 45-68; col 5, ln 1-6	5
Y	US 5,620,545 A (Braun et al.) 15 April 1997 (15.04.1997) col 14, 1n 60-66	6
Y	US 5,149,391 A (LI et al.) 22 September 1992 (22.09.1992) Col 3, ln 6-7; col 7, ln 6-9; col7, ln 52-61	8-9, 14-18
Y	US 4,248,938 A (Takata et al.) 03 February 1981 (03.02.1981) col2, ln 51-54; col 2, ln 20-25	10
Y	US 4,292,101 A (Reichert) 29 September 1981 (29.09.1981) col 2, ln 14-18 ;col 3 ln 68 to col 4 ln 3	11-13
Y	US 5,840,235 A (Yagi et al.) 24 November 1998 (24.11.1998) col 6 ln 50-51; Table 3	22-29, 32-33, 37

☒ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"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)
"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
"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
"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
"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
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 September 2012 (14.09.2012)	01 OCT 2012

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 12/48100

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,651,853 A (Wrigley et al.) 29 July 1997 (29.07.1997) col 1 ln 63 to col2, ln 23; col 3, ln 18-21; col 3, ln 22-31	30-33, 37, 40
Y	US 4,374,798 A (Mercer) 22 February 1983 (22.02.1983) Table 1	34-35, 39
Y	US 3,183,116 A (Schaarr) 11 May 1965 (11.05.1965) col 2, ln 25-29; col 7, ln 2-4	36
Y	US 4,317,792 A (Raley et al.) 02 March 1982 (02.03.1982) col 1;42-62	41
A	US 2009/0233041 A1 (Rasmussen) 17 September 2009 (17.09.2009) Entire Document	1-2, 2a, 3-41
A	US 4,748,070 A (Beehler) 31 May 1998 (31.05.1988) Entire Document	1-2, 2a, 3-41