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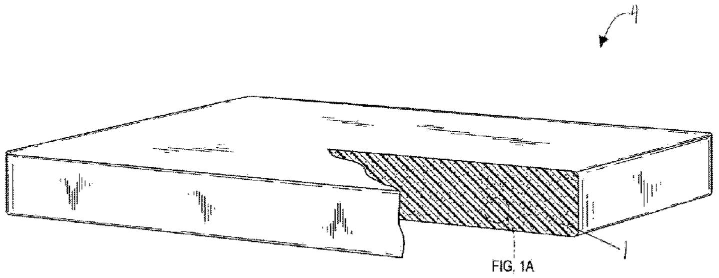

FIG. 1

(57) Abstract: A foam composite includes a matrix and a plurality of fibers embedded in the matrix. The matrix can include viscoelastic foam. Also disclosed herein are methods of manufacturing such a foam composite.

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FOAM COMPOSITE AND METHODS OF MAKING THE SAME

FIELD OF THE INVENTION

[0001] The present invention relates to foam composites, and more particularly to foam composites including fibers.

BACKGROUND OF THE INVENTION

[0002] Foam is often used in body supports such as mattresses, cushions, and slippers. Some foams have desirable characteristics such as cell size, recovery time, and hardness, but fail to have adequate tensile strength for use in the body support. Such foams can be reformulated to have adequate tensile strength for use in the body support. Reformulation of the foam, however, often adversely changes other properties of the foam, for example, hardness and recovery time.

SUMMARY OF THE INVENTION

[0003] The invention provides, in one aspect, a foam composite including a matrix and a plurality of fibers embedded in the matrix.

[0004] The matrix may include viscoelastic foam. The fibers may include at least one of natural fibers and synthetic fibers. The fibers may include a material selected from a group consisting of polyethylene, polypropylene, rayon, nylon, polyester, and any combination thereof. The polyethylene material may include at least one of low melt polyethylene, ultra-high molecular weight polyethylene, and E380F fibrillated high density polyethylene.

[0005] The fibers may include at least one of chemically interactive fibers and chemically inert fibers. The chemically interactive fibers may include at least one of rayon fibers, nylon fibers, and polyester fibers. The chemically inert fibers may include at least one of polyethylene fibers and polypropylene fibers. The polyethylene fibers may include at least one of low melt polyethylene fibers, ultra-high molecular weight polyethylene fibers, and E380F fibrillated high density polyethylene fibers.

[0006] The fibers may have a chop length of at least about 0.1 mm and no greater than about 5 mm. The fibers may have a chop length of at least about 0.7 mm and no greater than about 3.175 mm (1/8 inch). The fibers may have a diameter of at least about 14 microns and no greater than about 124 microns. The fibers may have a denier of at least about 1.3 dpf and no greater than about 10 dpf. The fibers may have a specific gravity of at least about 0.9 g/cm^3 and no greater than about 1.5 g/cm^3. The fibers may occupy less than about 5% by weight of the foam composite. The fibers may occupy less than about 2% by weight of the foam composite. The fibers may be present in an amount of about 0.65% to about 1.5% by weight of the foam composite.

[0007] The fibers may chemically interact with the viscoelastic foam in the matrix. In other embodiments, however, the fibers may be inert and may not chemically interact with the viscoelastic foam in the matrix. The viscoelastic foam may include a density of no less than about 30 kg/m^3 and no greater than about 150 kg/m^3. The viscoelastic foam may include a density of about 40 kg/m^3. A dynamic fatigue hardness loss of the foam composite may be less than a dynamic fatigue hardness loss of the matrix alone. The dynamic fatigue hardness loss of the foam composite may be less than about 50% of the dynamic fatigue hardness loss of the matrix alone.

[0008] The viscoelastic foam may include a density of about 80 kg/m^3. A dynamic fatigue hardness loss of the foam composite may be greater than a dynamic fatigue hardness loss of the matrix alone. The dynamic fatigue hardness loss of the foam composite may be about 32% greater than the dynamic fatigue hardness loss of the matrix alone.

[0009] The viscoelastic foam may include a hardness of at least about 20 N and no greater than about 80 N. The foam composite may have a tensile strength of about 10% to about 60% greater than a tensile strength of the matrix alone. The tensile strength may be a vertical tensile strength. The vertical tensile strength may be about 14% to about 53% greater than a vertical tensile strength of the matrix alone. The tensile strength may be a horizontal tensile strength. The horizontal tensile strength of the foam composite may be about 37% greater than a horizontal tensile strength of the matrix alone.

[0010] The foam composite may have an air permeation of at least about 3 times greater than an air permeation of the matrix alone.

[0011] The fibers may extend in generally the same direction within the matrix. In other embodiments, however, the fibers may be randomly oriented within the matrix. The fibers may have a shape including at least one of a branched shape and an unbranched shape. The fibers having the unbranched shape may include a cross-sectional shape of at least one of an irregular cross-sectional shape and a lobed cross-sectional shape. The fibers having the unbranched shape may extend in generally the same direction within the matrix. The fibers having the branched shape may be randomly oriented within the matrix.

[0012] The invention provides, in another aspect, a method of manufacturing a foam composite. The method includes providing fibers, a polyol, and an isocyanate, and mixing the fibers and one of the polyol and the isocyanate to form a first mixture. The method also includes adding the other of the polyol and the isocyanate to the first mixture to form a second mixture. The method further includes expanding the second mixture into the foam composite.

[0013] Mixing may occur at a speed of at least about 1000 rpm. In some embodiments, mixing may occur at a speed of about 1000 rpm to about 3000 rpm. Providing the fibers may include selecting fibers having a diameter of less than about 124 microns. The method may further include chopping the fibers to a length of less than about 5 mm prior to mixing the fibers. Expanding the second mixture may occur along an axis. Expanding the second mixture may cause the fibers to align in a direction that is generally parallel with the axis of expansion. In other embodiments, expanding the second mixture may cause the fibers to align in a direction that is generally perpendicular with the axis of expansion. Providing the fibers may include providing at least one of natural fibers and synthetic fibers. Providing the fibers may include selecting materials from a group consisting of low melt polyethylene, ultra-high molecular weight polyethylene, E380F fibrillated polyethylene pulp, polypropylene, rayon, nylon, polyester, and any combination thereof.

[0014] Other features and aspects of the invention will become apparent by consideration of the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] FIG. 1 is a perspective view of a mattress, in which a cutaway illustrates a foam composite in accordance with an embodiment of the invention.

[0016] FIG. 1A is a detailed view of the foam composite of FIG. 1.

[0017] FIG. 2 is a detailed view of a foam composite in accordance with a second embodiment of the invention.

[0018] Before any embodiments of the invention are explained in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of components set forth in the following description. The invention is capable of other embodiments and of being practiced or of being carried out in various ways.

Also, it is to be understood that the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting.

DETAILED DESCRIPTION

[0019] As illustrated in FIG. 1, the present invention relates to a foam composite 1 for use in a body support 4 (e.g., slippers, cushions, pillows, mattresses, etc.). The foam composite 1 includes a matrix 8 and fibers 12 embedded in the matrix 8 (FIG. 1A). The matrix 8 can include one or more types of foam. Many foams have desirable characteristics such as cell size, recovery time, glass transition temperature, hardness, and tan delta. Many of these foams, however, do not meet performance standards (e.g., tensile strength, dynamic fatigue, etc.) for use in body supports 4 like slippers, cushions, pillows, and mattresses. By embedding fibers 12 in the matrix 8, and thus the foam, the foam composite 1 can have an improved performance (e.g., increased tensile strength) as compared to the foam alone, thereby meeting performance standards for use in the body support 4. Additionally, the foam composite 1 may maintain the desirable characteristics of the foam. In other embodiments, the embedded fibers 12 may alter or improve the desirable characteristics of the foam.

[0020] The foam may be viscoelastic foam or non-viscoelastic foam (e.g., latex foam, high-resilience (HR) polyurethane foam, etc.). The viscoelastic foam may be polyurethane foam. Viscoelastic foam is sometimes referred to as "memory foam" or "low resilience foam." Coupled with the slow recovery characteristic of viscoelastic foam, the foam composite 1 can at least partially conform to a user's body or body portion (e.g., head, hips, feet, and the like; hereinafter referred to as "body"), thereby distributing the force applied by the user's body upon the foam composite 1. The foam composite 1 can provide a relatively soft and comfortable surface for the user's body.

[0021] In some embodiments, the viscoelastic foam has a hardness of at least about 20 N and no greater than about 80 N for desirable softness and body-conforming qualities. Alternatively, the viscoelastic foam may have a hardness of at least about 30 N and no greater than about 70 N. In still other alternative embodiments, the viscoelastic foam may have a hardness of at least about 40 N and no greater than about 60 N. Unless otherwise specified, the hardness of a material referred to herein is measured by exerting pressure from a plate against a sample of the material to a compression of 40 percent of an original thickness of the material at approximately room temperature (e.g., 21 to 23 degrees Celsius). The 40 percent compression is held for a set period of time, following the International Organization of Standardization (ISO) 2439 hardness measuring standard.

[0022] The viscoelastic foam can also have a density providing a relatively high degree of material durability. The density of the viscoelastic foam can impact other characteristics of the foam composite 1, such as the manner in which the foam composite 1 responds to pressure, and the feel of the foam composite 1. In some embodiments, the viscoelastic foam has a density of no less than about 30 kg/m^3 and no greater than about 150 kg/m^3. Alternatively, the viscoelastic foam may have a density of at least about 40 kg/m^3 and no greater than about 135 kg/m^3. In still other alternative embodiments, the viscoelastic foam may have a density of at least about 50 kg/m^3 and no greater than about 120 kg/m^3.

[0023] The viscoelastic foam can be made from non-reticulated or reticulated viscoelastic foam. Reticulated viscoelastic foam has characteristics that are well suited for use in the foam composite, including the enhanced ability to permit fluid movement through the reticulated viscoelastic foam, thereby providing enhanced air and/or heat movement within, through, and away from the foam composite 1. Reticulated foam is a cellular foam structure in which the cells of the foam are essentially skeletal. In other words, the cells of the reticulated foam are each defined by multiple apertured windows surrounded by struts. The cell windows of the reticulated foam can be entirely gone (leaving only the cell struts) or substantially gone. For example, the foam may be considered "reticulated" if at least 50 percent of the windows of the cells are missing (i.e., windows having apertures therethrough, or windows that are completely missing and therefore leaving only the cell struts). Such structures can be created by destruction or other removal of cell window material, or preventing the complete formation of cell windows during the manufacturing process.

[0024] In an alternative embodiment of the foam composite 1, the matrix 8 may include a non-viscoelastic foam such as a latex foam or a HR polyurethane foam. Such a latex foam may have a hardness of at least about 30 N and no greater than about 130 N for a desirable overall foam composite 1 firmness and "bounce." In still other alternative embodiments, the latex foam may have a hardness of at least about 40 N and no greater than about 120 N, or at least about 50 N and no greater than about 110 N. In some embodiments, the latex foam has a density of no less than about 40 kg/m^3 and no greater than about 100 kg/m^3. In still other alternative embodiments, the latex foam may have a density of at least about 50 kg/m^3 and no greater than about 100 kg/m^3, or at least about 60 kg/m^3 and no greater than about 100 kg/m^3.

[0025] In an alternative embodiment of the foam composite 1 in which the matrix 8 includes HR polyurethane foam, such a foam may include an expanded polymer (e.g., expanded ethylene vinyl acetate, polypropylene, polystyrene, or polyethylene), and the like. In some embodiments, the HR polyurethane has a hardness of at least about 80 N and no greater than about 200 N for a desirable overall foam composite 1 firmness and "bounce." In still other alternative embodiments, the HR polyurethane foam may have a hardness of at least about 90 N and no greater than about 190 N, or at least about 100 N and no greater than about 180 N.

[0026] The HR polyurethane foam may have a density which provides a reasonable degree of material durability to the foam composite 1. The HR polyurethane foam may also impact other characteristics of the foam composite 1, such as the manner in which the foam composite 1 responds to pressure. In some embodiments, the HR polyurethane foam has a density of no less than about 10 kg/m^3 and no greater than about 80 kg/m^3. In still other alternative embodiments, the HR polyurethane foam may have a density of no less than about 15 kg/m^3 and no greater than about 70 kg/m^3, or no less than about 20 kg/m^3 and no greater than about 60 kg/m^3.

[0027] As discussed above, the foam composite 1 includes fibers 12 embedded in the matrix 8 (FIG. 1A). The fibers 12 can be natural fibers or synthetic fibers. In some embodiments, the fibers 12 may be basophil (i.e., melamine) fibers, polylactic acid (i.e., PLA) fibers, or polyvinyl alcohol (i.e., PVA) fibers. In other embodiments, the fibers 12 can interact with the viscoelastic foam in the matrix 8. The interaction can be a chemical interaction such as a covalent bond or an intermolecular interaction. The intermolecular interaction can include, but is not limited to, hydrogen bonding, van der Waals forces, dipole-dipole forces, and hydrophobic interactions. The interactive fibers 12 can include any number of fibers or materials, for example, rayon fibers, nylon fibers, and polyester fibers. In some embodiments, the rayon fibers may be trilobal.

[0028] In still other embodiments, the fibers 12 can be inert and not chemically interact with the viscoelastic foam in the matrix 8. The inert fibers 12 can include any number of fibers or materials, for example, polyethylene fibers and polypropylene fibers. In some embodiments, the polyethylene fibers may include low melt polyethylene fibers, ultra-high molecular weight polyethylene fibers, and E380F fibrillated high density polyethylene fibers (i.e., "short stuff"). Low melt polyethylene may also be known as synthetic linear low-density polyethylene or LLDPE. Low melt polyethylene has a molecular weight of 35,000

Daltons, a melting point of 123 degrees Celsius, and a breaking tenacity of 1.0 gram of breaking force per denier of fiber (i.e., gpd). Ultra-high molecular weight polyethylene may also be known as synthetic high-modulus polyethylene, HMPE, high performance polyethylene, or HPPE. Ultra-high molecular weight polyethylene has a molecular weight of 4.5 to 6 million Daltons, a melting point of 147 degrees Celsius, and a breaking tenacity of 25.5 to 30.5 gpd.

[0029] The fibers 12 can have a chop length of at least about 0.05 millimeters (i.e., mm) and no greater than about 10 mm. Alternatively, the fibers 12 may have a chop length of at least about 0.1 mm and no greater than about 5 mm. In still other alternative embodiments, the fibers 12 may have a chop length of at least about 0.7 mm and no greater than about 3.175 mm (i.e., 1/8 inch). The fibers 12 can have the same chop length. Alternatively, the fibers 12 may have a randomized chop length.

[0030] The fibers 12 can also have a diameter of at least about 1 micron and no greater than about 250 microns. Alternatively, the fibers 12 can have a diameter of at least about 8 microns and no greater than about 185 microns. In still other alternative embodiments, the fibers 12 can have a diameter of at least about 14 microns and no greater than about 124 microns. The diameter of the fibers 12 can be related to the fiber unit denier (i.e., dpf). Particularly, the diameter (in microns) equals 11.89 times the square root of the denier (i.e., dpf) divided by the density (in grams per mL or grams per cm^3) of the fiber 12. Accordingly, fibers 12 of the same denier can have different diameters should the density of the respective materials from which they are made differ. In some embodiments, the fibers 12 can have a denier of at least about 0.1 dpf and no greater than about 20 dpf. Alternatively, the fibers 12 may have a denier of at least about 0.6 dpf and no greater than about 15 dpf. In still other alternative embodiments, the fibers 12 may have a denier of at least about 1.3 dpf and no greater than about 10 dpf.

[0031] The diameter and the chop length of the fibers 12 can be expressed as a ratio (i.e., chop length/diameter), which may also be known as an aspect ratio of the fibers 12. The aspect ratio of the fibers 12 can be at least about 0.0005 mm/micron and no greater than about 1 mm/micron. Alternatively, the aspect ratio of the fibers 12 may be at least about 0.0025 mm/micron and no greater than about 0.50 mm/micron. In still other alternative embodiments, the aspect ratio of the fibers 12 may be at least about 0.005 mm/micron and no greater than about 0.25 mm/micron.

[0032] The fibers 12 can have a specific gravity of at least about 0.09 grams per cubic centimeter (i.e., g/cm^3) and no greater than about 15 g/cm^3. Alternatively, the fibers 12 may have a specific gravity of at least about 0.1 g/cm^3 and no greater than about 8 g/cm^3. In still other alternative embodiments, the fibers 12 may have a specific gravity of at least about 0.9 g/cm^3 and no greater than about 1.5 g/cm^3. In further embodiments, the fibers 12 may have the features listed below in Table 1.

Table 1

Fiber	Denier (dpf)	Specific gravity (g/cm^3)	Diameter (microns)
Basofil	2.4	1.4	15.6
Nylon	3.0	1.14	19.3
PLA (polylactic acid)	1.3	1.25	12.1
Polyester	3.0	1.38	17.5
Polyethylene, low melt	6	0.96	74.3
Polyethylene, UHMW	10	0.96	123.8
Polypropylene	1.5	0.90	15.3
PVA (polyvinyl alcohol)	1.8	1.3	14.0
Rayon	4.5	1.5	20.6
Rayon, trilobal	3.0	1.5	16.8
'Short Stuff' E380F fibrillated high density polyethlyene			15

[0033] The fibers 12 can occupy less than about 5% by weight of the foam composite 1. Alternatively, the fibers 12 may occupy less than about 2% by weight of the foam composite 1. In still other alternative embodiments, the fibers 12 are present in an amount of about 0.65% to about 1.5% by weight of the foam composite 1. In some embodiments, the density of the fibers 12 can be varied by holding the percent by weight of the foam composite 1 constant, but changing the denier of the fibers 12. In still other alternative embodiments, the fibers 12 can occupy about 1 parts per hundred polyol (i.e., pphp) or about 0.5 pphp when the foam of the matrix is made from a polyol.

[0034] The fibers 12 can have an unbranched shape or a branched shape. The unbranched fibers 12 can have a cross-sectional shape that is irregular or lobed (i.e., having one or more distinct lobes or curved projection(s) as opposed to a circular cross-sectional shape). The unbranched fibers 12 can be parallel to or aligned with each other within the matrix 8 (FIG. 1A). In other words, the unbranched fibers 12 may extend in generally the same direction within the matrix. The branched fibers 12 can also be known as fibrillated fibers. The branched fibers 12 can be randomly oriented or aligned within the matrix 8. Alternatively, some of the branched fibers 12 may extend in a vertical direction within the matrix 8, while other branched fibers 12 may extend in a horizontal direction within the matrix 8 (FIG. 2).

[0035] The foam composite 1 can include both gross or macroscale properties and microscale properties that can be different from the macroscale and/or microscale properties of the matrix 8 alone. Macroscale properties can include, but are not limited to, tensile strength, dynamic fatigue, and compression set. Microscale properties can include, but are not limited to, glass transition temperature, hardness, and recovery time. The macroscale and/or microscale properties of the foam composite 1 can be altered by the type of fiber 12 (e.g., chemically interactive fibers, chemically inert fibers, etc.) embedded in the matrix 8.

[0036] In one example, a foam composite 1 including chemically inert fibers 12 may have improved or greater tensile strength, dynamic fatigue, compression set, or a combination thereof as compared to the matrix alone without alteration of the microscale properties. In other words, the chemically inert fibers 12 can lend strength to the foam composite 1 without altering the chemical composition of the matrix 8. In a second example, a foam composite 1 including chemically interactive fibers 12 may have both improved macroscale properties, and altered or changed microscale properties as compared to the matrix 8 alone.

[0037] The foam composite 1 can have a tensile strength of about 5% to about 80% greater than a tensile strength of the matrix 8 alone. Alternatively, the foam composite 1 may have a tensile strength of about 10% to about 60% greater than a tensile strength of the matrix 8 alone. In still other alternative embodiments, the foam composite 1 may have a tensile strength of about 14% to about 53% greater than a tensile strength of the matrix 8 alone. The tensile strength can be measured in either a vertical direction (hereinafter "vertical tensile strength"), or a horizontal direction (hereinafter "horizontal tensile strength"). The vertical tensile strength can extend in generally the same direction as the direction in which the viscoelastic foam in the matrix 8 expanded or rose during formation of the viscoelastic foam (i.e., foam rise profile or axis of expansion). In other words, the vertical tensile strength can extend in a direction generally parallel to the axis of the foam expansion. The vertical tensile strength of the foam composite can be about 5% to about 80% greater than a vertical tensile strength of the matrix alone. Alternatively, the vertical tensile strength of the foam composite 1 may be about 10% to about 60% greater than a vertical tensile strength of the matrix 8 alone. In still other alternative embodiments, the vertical tensile strength of the foam composite 1 may be about 14% to about 53% greater than a vertical tensile strength of the matrix 8 alone.

[0038] In other embodiments, the tensile strength may be a horizontal tensile strength. The horizontal tensile strength may extend in a direct generally perpendicular to the axis of foam expansion. The horizontal tensile strength of the foam composite 1 may be at about 17% to about 57% greater than a horizontal tensile strength of the matrix 8 alone. Alternatively, the horizontal tensile strength of the foam composite 1 may be about 27% to about 47% greater than a horizontal tensile strength of the matrix 8 alone. In still other alternative embodiments, the horizontal tensile strength of the foam composite 1 may be about 37% greater than a horizontal tensile strength of the matrix 8 alone.

[0039] Other characteristics of the foam composite 1 can include the foam rise profile or the axis of expansion, and the gel time of the viscoelastic foam in the matrix 8. Gel time can be the time required for the viscoelastic foam to solidify during formation of the viscoelastic foam. Additional characteristics may include the glass transition temperature (T_g) and tan delta of the viscoelastic foam. Tan delta can be a measure of the viscoelasticity of foam. The fibers 12 embedded in the matrix 8 of the foam composite 1 may not substantially alter or change the foam rise profile, gel time, glass transition temperature, and/or tan delta of the viscoelastic foam.

[0040] A hardness of the viscoelastic foam in the matrix 8 can be unaltered or unchanged by the fibers 12 embedded in the matrix 8 of the foam composite 1. Alternatively, the hardness of the viscoelastic foam in the matrix 8 may be altered or changed by the fibers 12 embedded in the matrix 8 of the foam composite 1. In still other alternative embodiments, the hardness of the viscoelastic foam may be altered or changed when the fibers 12 in the matrix 8 of the foam composite 1 are polyester fibers.

[0041] The foam composite 1 can have a dynamic fatigue hardness loss. The dynamic fatigue hardness loss can be less than the dynamic fatigue hardness loss of the matrix 8 alone. In some embodiments, the dynamic fatigue hardness loss of the foam composite 1 can be less than about 50% of the dynamic fatigue hardness loss of the matrix 8 alone. .The matrix 8 of such a foam composite 1 can include a microcellular foam having a density of about 40 kg/m^3. In other embodiments, the dynamic fatigue hardness loss of the foam composite 1 may be greater than a dynamic fatigue hardness loss of the matrix 8 alone. In still other alternative embodiments, the dynamic fatigue hardness loss of the foam composite 1 may be about 32% greater than the dynamic fatigue hardness loss of the matrix 8 alone. The matrix 8 of such a foam composite 1 may include a large-cell foam having a density of about 80 kg/m^3.

[0042] The foam composite 1 can have an air permeation of about 1.5 times to about 6 times greater than an air permeation of the matrix 8 alone. Air permeation is the flow rate of air through the foam composite 1. Alternatively, the foam composite 1 may have an air permeation of about 2 times to about 4 times greater than an air permeation of the matrix 8 alone. In still other alternative embodiments, the foam composite 1 may have an air permeation of about 3 times greater than an air permeation of the matrix 8 alone.

[0043] In other embodiments, the foam composite 1 may have the macroscale properties listed below in Table 2.

Table 2

Foam	Fiber	Dose (% by weight)	Results
Microcellular foam (40 kg/m^3)	Short stuff	0.65	25% increase in vertical tensile strength, dramatic drop (> 70%) in dynamic fatigue hardness loss
	Polypropylene, 1.5 dpf	0.65	22% increase in vertical tensile, dramatic drop in dynamic fatigue hardness loss
	Polyethylene, low melt, 6 dpf	0.65	14% increase in vertical tensile strength, dramatic drop in dynamic fatigue hardness loss
	Polyethylene, UHMW, 10 dpf	0.65	21% increase in vertical tensile strength, 14% drop in dynamic fatigue hardness loss
	Rayon, 4.5 dpf	0.65	Enhanced air permeation (>3 times reference sample)
	Nylon, 3.0 dpf	0.65	Enhanced air permeation (>3 times reference sample)
	Polyester, 3.0 dpf	0.65	Enhanced air permeation (>3 times reference sample)
	Rayon, 4.5 dpf	1.0	46% increase in vertical tensile strength
	Polyester, 3.0 dpf	1.5	18% increase in vertical tensile strength

Large-cell foam (80 kg/m^3)	Short stuff	0.8	53% increase in vertical tensile and 37% increase in horizontal tensile strength, 32% improved dynamic fatigue hardness loss

[0044] In manufacturing the foam composite 1, a polyol and an isocyanate can be used to make the viscoelastic foam in the matrix 8. In some embodiments, the fibers 12 can be embedded or placed in the matrix 8 by mixing or combining the fibers 12 with the polyol to form a first mixture. Mixing can occur at speeds of at least about 1000 rpm. Alternatively, mixing may occur at speeds of about 1000 rpm to about 3000 rpm. Prior to mixing the fibers 12 and polyol, the fibers 12 can be chopped or divided into lengths (e.g., 0.7mm, 1/8 inch, etc.) to prevent tangling of the fibers 12 during mixing. The isocyanate can then be added to the first mixture to form a second mixture. The second mixture can be expanded or rise into the foam composite.

[0045] In alternative embodiments of manufacturing the foam composite 1, the fibers 12 may be embedded in the matrix 8 by mixing the fibers 12 with the isocyanate to form the first mixture. The polyol may be added to the first mixture to form the second mixture, which may be expanded or rise into the foam composite 1.

[0046] When the second mixture expands into the foam composite 1, the expansion can cause the fibers 12 to align in a direction that is generally parallel with the axis of expansion. In some embodiments, the fibers 12 aligned parallel with the axis of the expansion can be unbranched fibers. In other embodiments, alignment of the fibers 12 parallel to the axis of expansion may improve the tensile strength of the foam composite 1 as compared to the matrix 8 alone. Such an improvement may be an improvement in the vertical tensile strength because the unbranched fibers 12 are aligned parallel with the axis of expansion.

[0047] Alternatively, expansion may cause some of the fibers 12 to align in a direction generally parallel with the axis of expansion, while other fibers 12 may align in a direction generally perpendicular with the axis of expansion. In some embodiments, fibers 12 aligning parallel and perpendicular to the axis of expansion may be branched fibers. In other embodiments, alignment of the fibers 12 both parallel and perpendicular to the axis of expansion may improve the tensile strength of the foam composite 1 as compared to the matrix 8 alone. Such an improvement may be an improvement in the both the vertical and horizontal tensile strengths because the branched fibers 12 align parallel and perpendicular to the axis of expansion. In other words, parallel alignment of the fibers 12 may improve the vertical tensile strength of the foam composite 1 as compared to the matrix 8 alone, while perpendicular alignment of the fibers 12 may improve the horizontal tensile strength of the foam composite 1 as compared to the matrix 8 alone.

[0048] In some embodiments, expanding the second mixture can include the rise of bubbles or vesicles along the axis of expansion, thereby promoting the rise of the viscoelastic foam in the matrix 8 of the foam composite 1. Such bubbles can be, but are not limited to, carbon dioxide bubbles. The bubbles may aide in the alignment of the fibers 12 during the rise of the bubbles along the axis of expansion.

[0049] Various features of the invention are set forth in the following claims.

CLAIMS

What is claimed is:

1. A foam composite comprising:

a matrix including viscoelastic foam; and

a plurality of fibers embedded in the matrix.

2. The foam composite of claim 1, wherein the fibers include at least one of natural fibers and synthetic fibers.

3. The foam composite of claim 1, wherein the fibers include a material selected from a group consisting of polyethylene, polypropylene, rayon, nylon, polyester, and any combination thereof.

4. The foam composite of claim 3, wherein the polyethylene material includes at least one of low melt polyethylene, ultra-high molecular weight polyethylene, and E380F fibrillated high density polyethylene.

5. The foam composite of claim 1, wherein the fibers include at least one of chemically interactive fibers and chemically inert fibers.

6. The foam composite of claim 5, wherein the chemically interactive fibers include at least one of rayon fibers, nylon fibers, and polyester fibers.

7. The foam composite of claim 5, wherein the chemically inert fibers include at least one of polyethylene fibers and polypropylene fibers.

8. The foam composite of claim 7, wherein the polyethylene fibers include at least one of low melt polyethylene fibers, ultra-high molecular weight polyethylene fibers, and E380F fibrillated high density polyethylene fibers.

9. The foam composite of claim 1, wherein the fibers have a chop length of at least about 0.1 mm and no greater than about 5 mm.

10. The foam composite of claim 9, wherein the fibers have a chop length of at least about 0.7 mm and no greater than about 3.175 mm (1/8 inch).

11. The foam composite of claim 1, wherein the fibers have a diameter of at least about 14 microns and no greater than about 124 microns.

12. The foam composite of claim 1, wherein the fibers have a denier of at least about 1.3 dpf and no greater than about 10 dpf.

13. The foam composite of claim 1, wherein the fibers have a specific gravity of at least about 0.9 g/cm^3 and no greater than about 1.5 g/cm^3.

14. The foam composite of claim 1, wherein the fibers occupy less than about 5% by weight of the foam composite.

15. The foam composite of claim 14, wherein the fibers occupy less than about 2% by weight of the foam composite.

16. The foam composite of claim 14, wherein the fibers are present in an amount of about 0.65% to about 1.5% by weight of the foam composite.

17. The foam composite of claim 1, wherein the fibers chemically interact with the viscoelastic foam in the matrix.

18. The foam composite of claim 1, wherein the fibers are inert and do not chemically interact with the viscoelastic foam in the matrix.

19. The foam composite of claim 1, wherein the viscoelastic foam includes a density of no less than about 30 kg/m^3 and no greater than about 150 kg/m^3.

20. The foam composite of claim 19, wherein the viscoelastic foam includes a density of about 40 kg/m^3.

21. The foam composite of claim 20, wherein a dynamic fatigue hardness loss of the foam composite is less than a dynamic fatigue hardness loss of the matrix alone.

22. The foam composite of claim 21, wherein the dynamic fatigue hardness loss of the foam composite is less than about 50% of the dynamic fatigue hardness loss of the matrix alone.

23. The foam composite of claim 19, wherein the viscoelastic foam includes a density of about 80 kg/m^3.

24. The foam composite of claim 23, wherein a dynamic fatigue hardness loss of the foam composite is greater than a dynamic fatigue hardness loss of the matrix alone.

25. The foam composite of claim 24, wherein the dynamic fatigue hardness loss of the foam composite is about 32% greater than the dynamic fatigue hardness loss of the matrix alone.

26. The foam composite of claim 1, wherein the viscoelastic foam includes a hardness of at least about 20 N and no greater than about 80 N.

27. The foam composite of claim 1, wherein the foam composite has a tensile strength of about 10% to about 60% greater than a tensile strength of the matrix alone.

28. The foam composite of claim 27, wherein the tensile strength is a vertical tensile strength.

29. The foam composite of claim 28, wherein the vertical tensile strength of the foam composite is about 14% to about 53% greater than a vertical tensile strength of the matrix alone.

30. The foam composite of claim 27, wherein the tensile strength is a horizontal tensile strength.

31. The foam composite of claim 30, wherein the horizontal tensile strength of the foam composite is about 37% greater than a horizontal tensile strength of the matrix alone.

32. The foam composite of claim 1, wherein the foam composite has an air permeation of at least about 3 times greater than an air permeation of the matrix alone.

33. The foam composite of claim 1, wherein the fibers extend in generally the same direction within the matrix.

34. The foam composite of claim 1, wherein the fibers are randomly oriented within the matrix.

35. The foam composite of claim 1, wherein the fibers have a shape including at least one of a branched shape and an unbranched shape.

36. The foam composite of claim 35, wherein the fibers having the unbranched shape include a cross-sectional shape of at least one of an irregular cross-sectional shape and a lobed cross-sectional shape.

37. The foam composite of claim 35, wherein the fibers having the unbranched shape extend in generally the same direction within the matrix.

38. The foam composite of claim 35, wherein the fibers having the branched shape are randomly oriented within the matrix.

39. A method of manufacturing a foam composite, the method comprising:

providing fibers, a polyol, and an isocyanate;

mixing the fibers and one of the polyol and the isocyanate to form a first mixture;

adding the other of the polyol and the isocyanate to the first mixture to form a second mixture; and

expanding the second mixture into the foam composite.

40. The method of claim 39, wherein mixing occurs at a speed of at least about 1000 rpm.

41. The method of claim 40, wherein mixing occurs at a speed of about 1000 rpm to about 3000 rpm.

42. The method of claim 39, wherein providing the fibers includes selecting fibers having a diameter of less than about 124 microns.

43. The method of claim 39, further comprising chopping the fibers to a length of less than about 5 mm prior to mixing the fibers.

44. The method of claim 39, wherein expanding the second mixture occurs along an axis.

45. The method of claim 39, wherein expanding the second mixture causes the fibers to align in a direction that is generally parallel with the axis of expansion.

46. The method of claim 45, wherein expanding the second mixture causes the fibers to align in a direction that is generally perpendicular with the axis of expansion.

47. The method of claim 39, wherein providing the fibers includes providing at least one of natural fibers and synthetic fibers.

48. The method claim 39, wherein providing the fibers includes selecting materials from a group consisting of low melt polyethylene, ultra-high molecular weight polyethylene, E380F fibrillated polyethylene pulp, polypropylene, rayon, nylon, polyester, and any combination thereof.

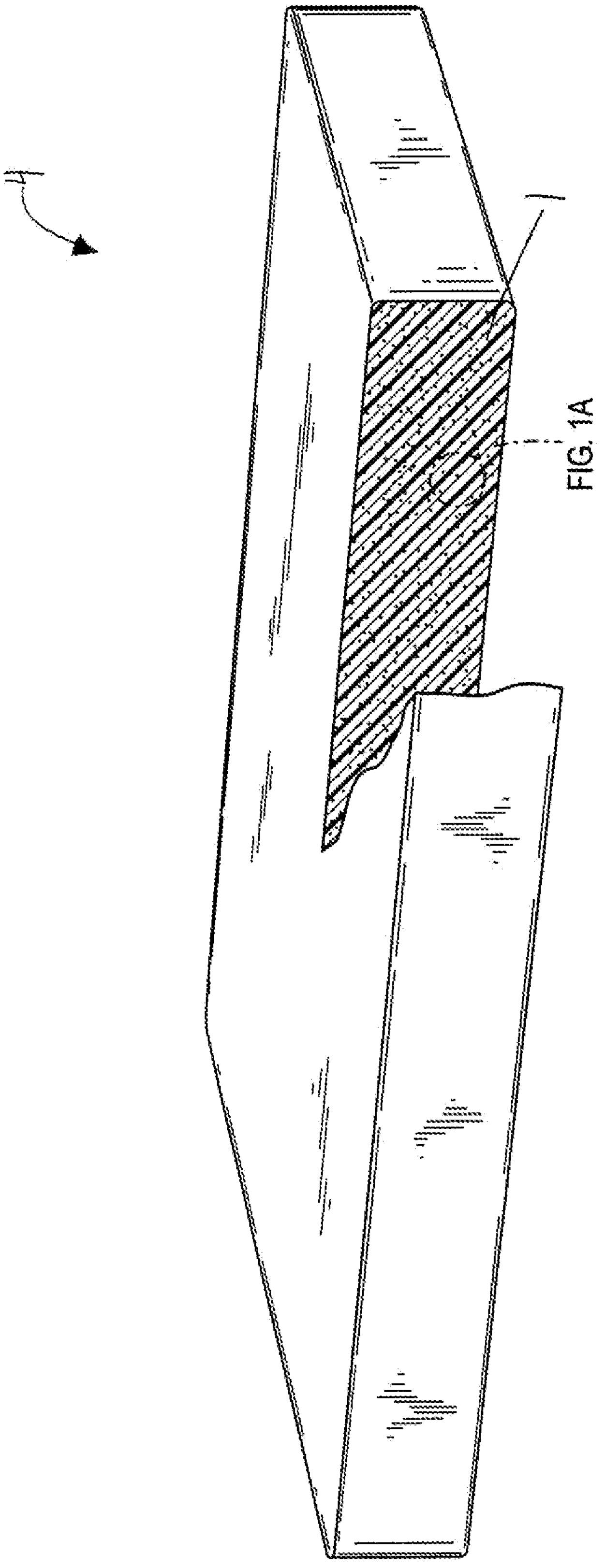

FIG. 1

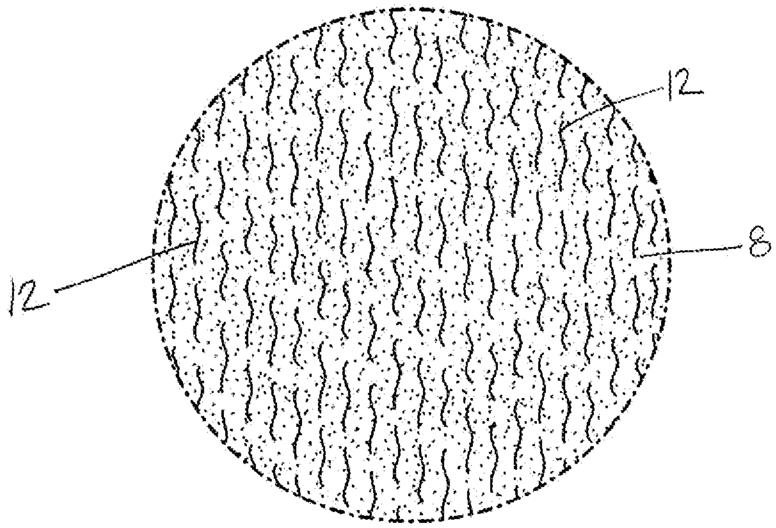

FIG. 1A

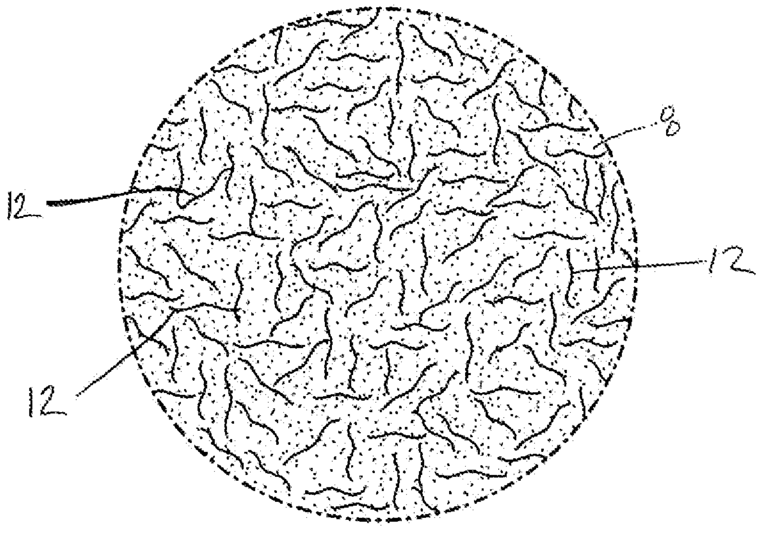

FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/032018

A. CLASSIFICATION OF SUBJECT MATTER

C08J 9/00(2006.01)i, C08J 5/04(2006.01)i, C08K 7/02(2006.01)i, C08G 18/06(2006.01)i, C08G 101/00(2006.01)n

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)
C08J 9/00; B32B 5/22; C08J 9/16; B32B 3/00; C08G 18/00; B32B 5/28; A47C 16/00; C08J 5/04; C08K 7/02; C08G 18/06; C08G 101/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: foam composite, matrix, fiber, viscoelastic foam, tensile strength, air permeation, polyol, isocyanate

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2011-038084 A1 (FILTRONA RICHMOND, INC.) 31 March 2011 See abstract, claims 1, 2, 9, 10, 13, 15, 16, 20, 27, 28, paragraphs [0002], [0007], [0009], [0015]-[0018], [0021], [0027], [0030]-[0032], [0035], [0041]-[0043] and table 1.	1-48
X	US 2006-0106124 A1 (FINK, J. T. et al.) 18 May 2006 See abstract, claims 1, 5, 11, 25, 29 and paragraphs [0002], [0012], [0019], [0028], [0030].	1-48
A	US 2004-0059010 A1 (NUTT, S. R. et al.) 25 March 2004 See abstract, claims 1, 2, 7, 10-12 and paragraphs [0007], [0009], [0033]-[0035], [0038], [0051].	1-48
A	WO 2010-075229 A1 (TEMPUR-PEDIC MANAGEMENT, INC.) 01 July 2010 See abstract, claims 1, 13 and paragraphs [0007]-[0009], [0016]-[0018].	1-48
A	WO 2010-075300 A1 (TEMPUR-PEDIC MANAGEMENT, INC.) 01 July 2010 See abstract, claims 1, 2 and paragraphs [0007], [0017], [0018].	1-48

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* 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 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 19 December 2013 (19.12.2013)	Date of mailing of the international search report **23 December 2013 (23.12.2013)**
Name and mailing address of the ISA/KR Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea Facsimile No. +82-42-472-7140	Authorized officer HEO, Joo Hyung Telephone No. +82-42-481-8150

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2013/032018

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2011-038084 A1	31/03/2011	EP 2480408 A1	01/08/2012
		US 2011-0070423 A1	24/03/2011
US 2006-0106124 A1	18/05/2006	None	
US 2004-0059010 A1	25/03/2004	AU 2003-256674 A1	09/02/2004
		EP 1551910 A2	13/07/2005
		EP 1551910 A4	09/05/2007
		US 6864297 B2	08/03/2005
		WO 2004-009681 A2	29/01/2004
		WO 2004-009681 A3	08/07/2004
WO 2010-075229 A1	01/07/2010	CA 2747967 A1	01/07/2010
		CN 102292209 A	21/12/2011
		EP 2373483 A1	12/10/2011
		EP 2373483 A4	09/05/2012
		JP 2012-513247 A	14/06/2012
		US 2011-256380 A1	20/10/2011
WO 2010-075300 A1	01/07/2010	None	