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(54) Energy-dissipating articles, materials and fibers

(57) A fiber (1, 1a) includes at least a first portion (2, 2a) extending axially and including a shear thickening fluid. The fiber (1, 1a) further includes at least a second portion (4, 4a) extending radially outwardly from the first portion (2, 2a). The second portion (2, 2a) extends axially and radially encompasses the first portion (2, 2a) over a length thereof. The shear thickening fluid may, for example, include particles suspended in a liquid phase. The second portion (4, 4a) may, for example, include an abrasion resistant material. The fiber (1, 1a) may further include at least a third portion (8a) extending axially and positioned radially inward of the first portion (2a). The third portion (8a) may, for example, include a material having a higher strength than the second portion (4a).

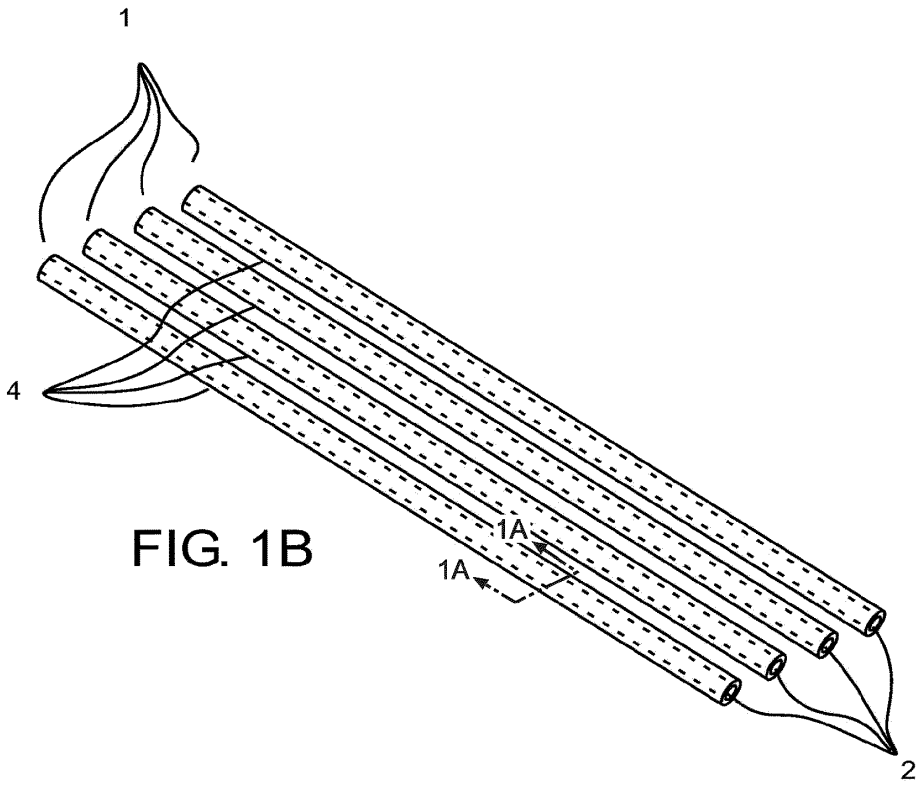

FIG. 1B

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Description

BACKGROUND OF THE INVENTION

[0001] Fibers and structures formed therefrom have proven to be acceptable for various applications. Such fibers and structures formed therefrom are nevertheless susceptible to improvements that may enhance the overall performance of the fiber and structure formed therefrom. Therefore, a need exists in the art for improved fibers and structures formed therefrom that advance the art.

SUMMARY OF THE INVENTION

[0002] In one aspect, a fiber includes at least a first portion extending axially and including a shear thickening fluid. The fiber further includes at least a second portion radially outward from the first portion. The second portion extends axially and radially encompasses the first portion over a length thereof. The shear thickening fluid may, for example, include particles suspended in a liquid phase. In a number of embodiments, the particles include at least one of an oxide, calcium carbonate or a polymer. For example, the particles may be $Si0_2$.

[0003] In a number of embodiments, the second portion includes at least one polymer. The at least one polymer of the second portion may, for example, be processible from a melt phase. In a number of embodiments, the at least one polymer of the second portion is a nylon, a polyester, a polypropylene, or a polyethylene.

[0004] The second portion may, for example, include an abrasion resistant material. In a number of embodiments, the abrasion resistant material is an abrasion resistant polymer. The fiber may further include a third portion extending axially and positioned radially inward of the first portion. The third portion may, for example, include a material having a higher strength than the second portion. The third portion may, for example, include at least one of a high- strength polymeric material or a metallic material.

[0005] In another aspect, a material includes a plurality of fibers. As described above, each of the plurality of fibers includes at least a first portion extending axially and including a shear thickening fluid. Each of the plurality of fibers further includes at least a second portion radially outward from the first portion. The second portion extends axially and radially encompasses the first portion over a length thereof.

[0006] In a further aspect, a fabric includes a plurality of fibers. As described above, each of the plurality of fibers includes at least a first portion extending axially and including a shear thickening fluid. Each of the plurality of fibers further includes at least a second portion radially outward from the first portion. The second portion extends axially and radially encompasses the first portion over a length thereof. The plurality of fibers may, for example, be woven into the fabric. The plurality of fibers may also be nonwoven. The plurality of fibers may, for example, be arranged in a unidirectional manner or in a random manner.

[0007] In still a further aspect, a ballistic panel includes at least one layer of a material including a plurality of fibers. As described above, each of the plurality of fibers includes at least a first portion extending axially and including a shear thickening fluid. Each of the plurality of fibers further includes at least a second portion radially outward from the first portion. The second portion extends axially and radially encompasses the first portion over a length thereof.

[0008] The present invention, along with the attributes and attendant advantages thereof, will best be appreciated and understood in view of the following detailed description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Figure 1A illustrates a cross-sectional view of an embodiment of a fiber of the subassembly of Figure 1B along line 1A-1A thereof including a polymeric sheath or outer portion enclosing a core or inner portion of a shear thickening fluid.

[0010] Figure 1B illustrates a perspective view of a plurality of fibers hereof oriented generally parallel to each other, wherein the fiber ends are cut to expose the inner core.

[0011] Figure 1C illustrates a cross-sectional view of another embodiment of a fiber of the subassembly of Figure 1D along line 1C-1C thereof including a first portion of a shear thickening fluid encompassed by a second portion of a polymeric material and a third portion radially inward of the first portion.

[0012] Figure 1D illustrates a perspective view of a plurality of fibers hereof oriented generally parallel to each other, wherein the fiber ends are cut to expose the inner core.

[0013] Figure 2 illustrates a top plan view of the front of an embodiment of an article of body armor including a fabric as illustrated in Figures 1A and 1B, wherein a front ballistic panel assembly interior to a vest carrier is shown in dashed lines.

[0014] Figure 3 illustrates a top plan view of the rear of the article of body armor of Figure 2, wherein the rear closure sections of the opposing closure mechanisms are folded back, wherein a rear ballistic panel assembly interior to the vest carrier is shown in dashed lines.

[0015] Figure 4A illustrates a top plan view of an embodiment of a subassembly for use in forming a front ballistic panel assembly of the article of body armor of Figure 2.

[0016] Figure 4B illustrates a top plan view of an embodiment of a subassembly for use in forming a rear ballistic panel assembly of the article of body armor of Figure 2.

[0017] Figure 4C illustrates a cross-sectional view of

the subassembly of Figure 4A along line A-A thereof.

DETAILED DESCRIPTION OF THE INVENTION

[0018] As used herein and in the appended claims, the singular forms "a," "an", and "the" include plural references unless the content clearly dictates otherwise. Thus, for example, reference to "a fiber" includes a plurality of such fibers and equivalents thereof known to those skilled in the art, and so forth, and reference to "the fiber" is a reference to one or more such fibers and equivalents thereof known to those skilled in the art, and so forth.

[0019] In a number of embodiments of fibers hereof, a fiber 1 includes at least a first portion or layer 2 of a shear thickening fluid as illustrated in Figures 1A and 1B. First portion or layer 2 extends axially through at least a portion of fiber 1 and typically through the entire fiber. Fiber 1 further includes at least a second axially extending portion or layer 4 (for example, formed from a polymeric material) which is positioned radially outward of first portion 2 and radially encompasses first portion 2 to retain the shear thickening fluid within fiber 1 in the manner of, for example, a sheath.

[0020] In a number of embodiments, a sheath (second portion 4) and core (first portion 2) fiber is extruded wherein the sheath of second layer 4 is formed from one or more polymers such as nylon 6, nylon 6,6 polyester, polypropylene, polyethylene (for example, an ultra-high-molecular-weight polyethylene such as DYNEEMA®, available from DSM, of Heelen, Netherlands) SPECTRA® available from Honeywell, Inc.) and/or other polymers and the core of the fiber is a dilatant or shear thickening fluid (STF). In a number of embodiments, the polymer or polymers of second portion 4 are processed/extruded from a melt phase.

[0021] Fibers hereof can include other portions or layers. For example, multiple layers of shear thickening fluids encompassed by, for example, polymer layers in a generally alternating concentric fashion. Figure 1C illustrates another embodiment of a fiber 1a including at least a first axially extending portion or layer 2a includes a shear thickening fluid. As with fiber 1, fiber 1a further includes at least a second axially extending portion or layer 4a (for example, formed from a polymeric material) which is positioned radially outward of first portion 2a and radially encompasses first portion 2a to retain the shear thickening fluid within fiber 1a. In the embodiment illustrated in Figure 1C, fiber 1a further includes a third axially extending portion 8a encompassed by second portion 4a. Second portion 4a may, for example, be formed from an abrasion resistant material such as an abrasion resistant polymer. In a number of embodiments, abrasion resistant materials used herein have, for example, an abrasion value of at least 1000 cycles, at least 1500 cycles or at least 1900 cycles when tested according to ASTM 3884. Third portion 8a may, for example, be formed from a high strength material (for example, a high strength polymer such as DYNEEMA or SPECTRA) or of a conductive metallic material. In a number of embodiments, high materials used herein have, for example, a tensile strength of at least 0.25 gigapascals, (GPa), at least 0.75 GPa, at least 1.5 GPa or at least 2.25 GPa.

[0022] STF suitable for use herein can, for example, be formed as particles suspended in a liquid phase/solvent (for example, an organic solvent or an aqueous solvent). The particles used can be made of various materials, including, but not limited to, $Si0_2$ (silica) or other oxides, $Si0_2$ or other oxides with a polymer (for example, polyethylene glycol), calcium carbonate, or polymers, such as polystyrene, polymethylmethacrylate, polyisobutenes (for example, OPPANOL®, available from BASF Aktiengesellschaft of Ludwigshafen, Germany), or other polymers from emulsion polymerization. The particles can be stabilized in solution or dispersed by charge, Brownian motion, adsorbed surfactants, and adsorbed or grafted polymers, polyelectrolytes, polyampholytes, or oligomers. Particle shapes include spherical particles, elliptical particles, or disk-like or clay particles. The particles may be synthetic and/or naturally occurring minerals. Also, the particles can be either monodisperse, bidisperse, or polydisperse in size and shape. In a number of embodiments, particles having a particle size less than, for example, 100 microns may be used in forming STFs for use herein.

[0023] The solvents or liquid phases used to form the STFs can, for example, be aqueous in nature (i.e. water with or without added salts, such as sodium chloride, and buffers to control pH) for electrostatically stabilized or polymer stabilized particles, or organic (such as ethylene glycol, polyethylene glycol, ethanol etc.), or silicon based (such as silicon oils, phenyltrimethicone). The liquid phase can also be composed of compatible mixtures of liquids, and may, for example, include free surfactants, polymers, and oligomers. The liquids should be environmentally stable so that they remain integral to the fabric and suspended particles during service.

[0024] The particles are suspended in the liquid to produce a fluid that has shear thickening properties. Shear thickening does not require a dilatant response, that is, it may not be associated with an increase in volume such as often observed in dry powders or sometimes in suspensions of larger particles (greater than 100 microns).

[0025] The fibers, yarns, fabrics (for example, woven fabrics or nonwoven fabrics), materials and/or articles hereof provide a number of advantages over fibers coated or impregnated with a dilatant or an STF. For example, the STF is contained in fluid form in the core of the fibers hereof. STF applied in a secondary operation such as coating or impregnation is not contained. By containing the STF in the fibers hereof, the STF is much more robust and stable and less likely to evaporate and/or degrade under higher temperature conditions (for example, at ambient summer temperatures or higher temperatures). Containing the STF in the fiber also provides more uniformity and consistency of the STF than current methods

which involve application processes such as coating and/or impregnating. Coating and impregnation methods are, for example, susceptible to variations in thickness and coverage uniformity. Containing the STF in the fiber will also improve the overall durability of the STF, including its abrasion resistance, as compared to STFs applied to fibers in a secondary operation. Energy dissipation may, however, be further improved via coating or impregnating the exterior of fabrics hereof with an STF to enhance inter-fiber friction.

[0026] Fabrics formed from fibers hereof can, for example, be used to mitigate blunt force trauma in a ballistic vest when impacted by a projectile (bullet, spike, blade, etc). Fibers hereof can also be used to mitigate impact damage in other applications (for example, in hardhats, in advanced combat helmets (ACH), in shielding for machinery etc.).

[0027] Figure 2 illustrates a representative embodiment of an article of body armor 10 in which a body armor carrier is in the form of a vest 20. Vest 20 can be used alone or in operative connection with a connected garment such as a shirt (not shown). For example, an exterior shell fabric of the body armor can be sewn to the shirt. A user of body armor 10 first dons body armor 10 and then adjusts the fit of body armor vest 20 using one or more side closure mechanisms. Lightweight outer carriers in the form of vests similar to vest 20 are available from Mine Safety Appliances Company (MSA) of Pittsburgh, Pennsylvania under the mark PARACLETE®. Vest 20 is provided as a representative example of use of a fabric of fibers hereof in a ballistic panel. One skilled in the art appreciates that the fibers hereof are suitable for use in many different uses.

[0028] As described above, body armor 10 includes ballistic panel assemblies or ballistic resistant panel assemblies that provide resistance to, for example, edged weapons, sharp objects, and ballistic threats. As illustrated with dashed lines in, for example, Figure 2, vest 20 includes a generally contiguous (in coverage), flexible front ballistic panel assembly 200. Ballistic panel assembly 200 can be formed as one, integral section or assembly or as a plurality of separate sections or assemblies. However, the coverage provided by ballistic panel assembly 200 is preferably contiguous. Front ballistic panel assembly 200 includes side sections 210a and 210b adapted to extend around the side of a user. Ballistic panel assembly 200, including side sections 210a and 210b, is enclosed within an outer shell of fabric forming the front of carrier or vest 20. As illustrated with dashed lines in, for example, Figure 3, vest 20 also includes a generally contiguous (in coverage), flexible rear ballistic panel assembly 300. Like front ballistic panel assembly 200, rear ballistic panel assembly 300 can be formed as one section or assembly or as a plurality of separate sections or assemblies. Rear ballistic panel assembly 300 includes side sections 310a and 310b adapted to extend around the side of a user. Like ballistic panel assembly 200, ballistic panel assembly 300, including side sections 310a and 310b, is enclosed within an outer shell of fabric forming the rear of carrier or vest 20.

[0029] Figures 4A through 4C illustrate one embodiment of a ballistic panel assembly or ballistic package of the present invention Figure 4A illustrates a flexible subassembly 230 for use in forming front ballistic panel assembly 200, while Figure 4B illustrates a flexible subassembly 330 for use in forming rear ballistic panel assembly 300. Subassemblies 230 and 330 can, for example, be designed for Type II level of ballistic performance as set forth in Section 2.2 of NIJ Standard-0101.06. Performance standards for ballistic panels are, for example, set forth in National Institute of Justice (NIJ) Standard-0101.06, "Ballistic Resistance of Body Armor". NIJ Standard-0101.06 is a technical document that specifies the minimum performance requirements that equipment must meet to satisfy the requirements of criminal justice agencies and the methods that shall be used to test this performance. This standard is used to determine which body armor models meet the minimum performance requirements for inclusion on the NIJ Compliant Products List.

[0030] In the embodiment of Figures 4A through 4B, each of front ballistic panel assembly 200 and rear ballistic panel assembly 300 can, for example, be manufactured using generally the same materials and procedures and differ generally only in shape. Figure 4C illustrates a cross-sectional view of subassembly 230 along line A-A of Figure 4A. A cross-section of subassembly 330 along line A-A of Figure 4B (which is not shown) is identical to that of subassembly 230.

[0031] As illustrated in Figure 4C, subassembly 230 (as well as subassembly 330) includes, for example, a multi-ply (for example, a 2-ply) layer 232 of an aramid fabric on the front, outer or strike face thereof. The term "aramid" is short for aromatic polyamide. In one embodiment, layer 232 included two plies of GOLD FLEX® material available from Honeywell. No adhesive was placed between the plies of GOLD FLEX material. Without limitation to any particular mechanism of operation, layer 232 is believed to operate, at least in part, to alter the shape, deform or flatten a projectile or bullet impacting layer 232 so that it has less potential to penetrate any adjacent layer(s).

[0032] Adjacent to layer 232 is a layer 234 including, for example, a plurality of plies of, for example, an aramid fabric. In one embodiment, layer 234 included, for example, multiple plies of TWARON® woven fabric available from Teijin Aramid BV of Amhem, The Netherlands. TWARON material is a very strong, light para-aramid (poly-paraphenylene terephthalamide), which has a high tensile strength and is thermally stable. TWARON fabrics also exhibit high impact and chemical resistance. No adhesive was used between the plies of TWARON fabric in layer 234. Without limitation to any particular mechanism of operation, it is believed that the projectile or bullet is stopped within layer 234 as a result, at least in part, of elongation and breakage of the high tensile strength fib-

ers of the TWARON fabric.

[0033] Adjacent to layer 234 is a layer 236 including, for example, a fabric formed from fibers 1 that forms the back, inner or wear face of subassembly 230. Layer 236 can, for example, be a single-ply layer or a multi-ply layer of such a fabric material with no adhesive between the plies thereof. The diameter and/or other parameter of the fibers can be varied or optimized to achieve desired results via application of established engineering principles. Layer 236 can operate, at least in part, to limit deformation of the wear face of subassembly 230 upon a ballistic strike thereto to limit the amount of blunt force trauma experienced by a user of vest 20. In that regard (and, once again, without limitation to any particular mechanism of operation,), layer 236 can, for example, operate to distribute rearward propagating force from the projectile or bullet over the surface area thereof and assists in limiting backface deformation or backface signature (BFS) as defined in Section 3.8 of NIJ Standard-0101.06. In that regard, the allowable BFS is the greatest extent of indentation in a backing material caused by a nonperforating impact on tested armor. As set forth in Section 3.9 of NIJ Standard-0101.06, the backing material is a homogeneous block of nonhardening, oil-based modeling clay placed in contact with the back of the armor panel during ballistic testing.

[0034] The foregoing description and accompanying drawings set forth the preferred embodiments of the invention at the present time. Various modifications, additions and alternative designs will, of course, become apparent to those skilled in the art in light of the foregoing teachings without departing from the scope of the invention. The scope of the invention is indicated by the following claims rather than by the foregoing description. All changes and variations that fall within the meaning and range of equivalency of the claims are to be embraced within their scope.

Claims

1. A fiber (1, 1a) comprising:

at least a first portion (2, 2a) extending axially and comprising a shear thickening fluid, and
at least a second portion (4, 4a) extending radially outwardly from the first portion (2, 2a), the second portion (4, 4a) extending axially and radially encompassing the first portion (2, 2a).

2. The fiber (1, 1a) of claim 1, wherein the shear thickening fluid comprises:

particles suspended in a liquid phase.

3. The fiber (1, 1a) of claim 2, wherein the particles comprise:

at least one of an oxide, calcium carbonate or a polymer;
optionally wherein the oxide is $Si0_2$;
optionally wherein the polymer is a polystyrene, a polymethylmethacrylate or a polyisobutene.

4. The fiber (1, 1a) of any one of the preceding claims, wherein the second portion (4, 4a) comprises:

at least one polymer;
optionally wherein the polymer of the second portion (4, 4a) is a nylon, a polyester, a polypropylene, or a polyethylene;
optionally wherein the polymer of the second portion (4, 4a) is processible from a melt phase.

5. The fiber (1, 1a) of any one of the preceding claims, wherein the second portion (4, 4a) comprises an abrasion resistant material;
optionally wherein the abrasion resistant material is an abrasion resistant polymer.

6. The fiber (1a) of any one of the preceding claims, further comprising:

at least a third portion (8a) extending axially and positioned radially inwardly of the first portion (2a), the third portion (8a) including a material having a higher strength than the second portion (4a);

optionally wherein the third portion (8a) comprises:

at least one of a high-strength polymeric material or a metallic material.

7. The fiber (1, 1a) of any one of the preceding claims, further comprising:

a flexible subassembly (230, 330) including:

an outer multi-ply strike-face layer (232), and
a middle multi-play layer (234),
wherein an outwardly-facing surface of the middle multi-play layer (234) is disposed adjacent the outer multi-ply strike-face layer (232), wherein an inwardly-facing surface of the middle multi-play layer (234) is disposed adjacent a fabric layer (236), wherein the fabric layer (236) includes the fiber (1, 1a).

8. A fabric layer (236), comprising:

a plurality of fibers (1, 1a),
wherein each of the plurality of fibers (1, 1a) is according to any one of the preceding claims.

9. The fabric layer (236) of claim 8, wherein the fabric layer (236) is an inner layer of a flexible subassembly (230, 330), wherein the flexible subassembly (230, 330) comprises:

an outer multi-ply strike-face layer (232) including a first aramid fabric,
a middle multi-play layer (234) including a second aramid fabric, wherein an outwardly-facing surface of the middle multi-play layer (234) is disposed adjacent the outer multi-ply strike-face layer (232), wherein an inwardly-facing surface of the middle multi-play layer (234) is disposed adjacent the fabric layer (236).

10. The fiber (1, 1a) of claim 7 or the fabric layer (236) of claim 9, further comprising:

a ballistic panel assembly (200, 300), wherein the ballistic panel assembly (200, 300) includes the flexible subassembly (230, 330).

11. A ballistic panel assembly (200, 300), comprising:

at least one layer (236) of a material including a plurality of fibers (1, 1a), each of the plurality of fibers (1, 1a) being according to any one of claims 1 to 7.

12. The ballistic panel assembly (200, 300) of claim 11, wherein the at least one layer (236) of the material including the plurality of fibers (1, 1a) are formed into a fabric.

13. The fabric layer of claim 8 or the ballistic panel assembly (200, 300) of claim 12, wherein the plurality of fibers (1, 1a) forming the fabric are woven.

14. The fabric layer of claim 8 or the ballistic panel assembly (200, 300) of claim 12, wherein the plurality of fibers (1, 1a) forming the fabric are nonwoven.

15. The fabric layer of claim 8, 13 or 14 or the ballistic panel assembly (200, 300) of claim 12, 13 or 14, wherein the plurality of fibers (1, 1a) forming the fabric are arranged in a unidirectional or random manner.

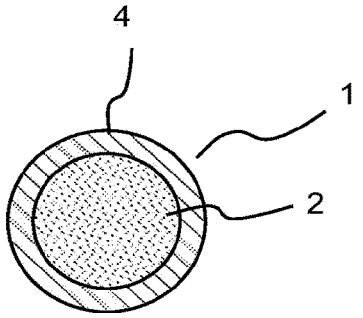


FIG. 1A

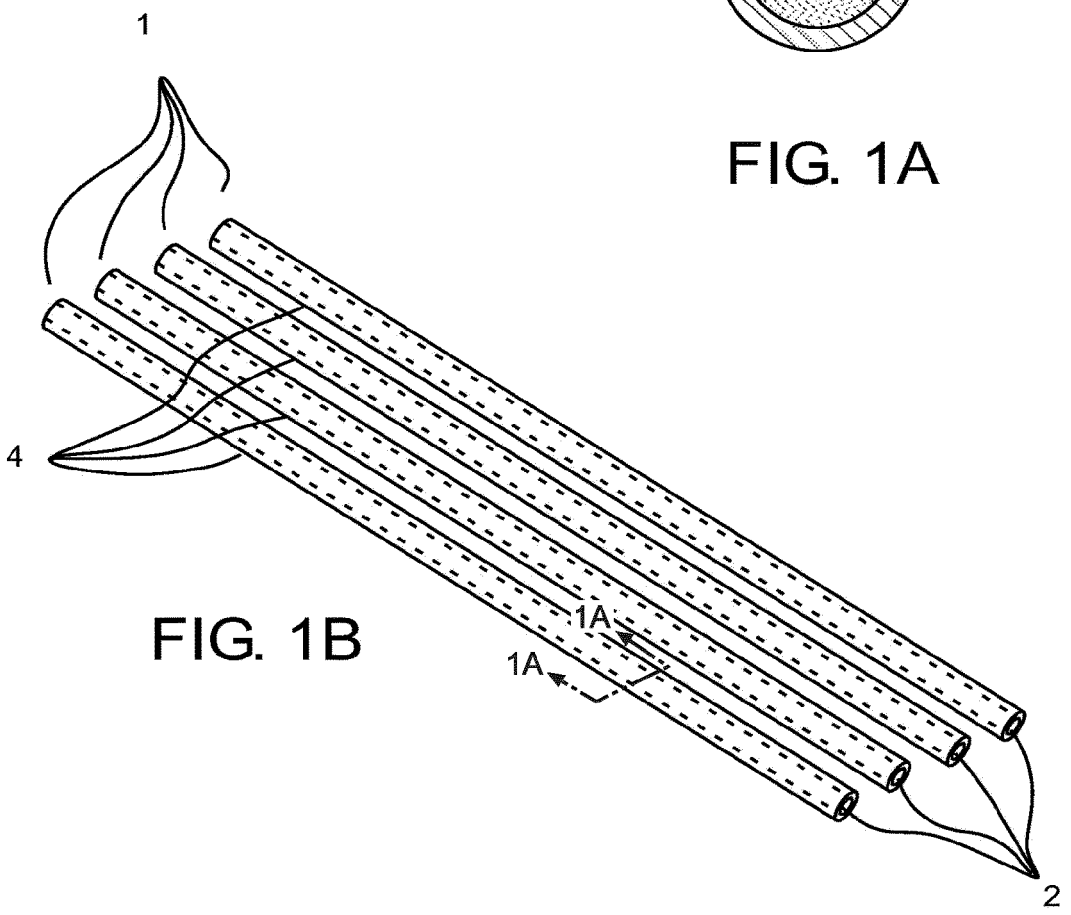


FIG. 1B

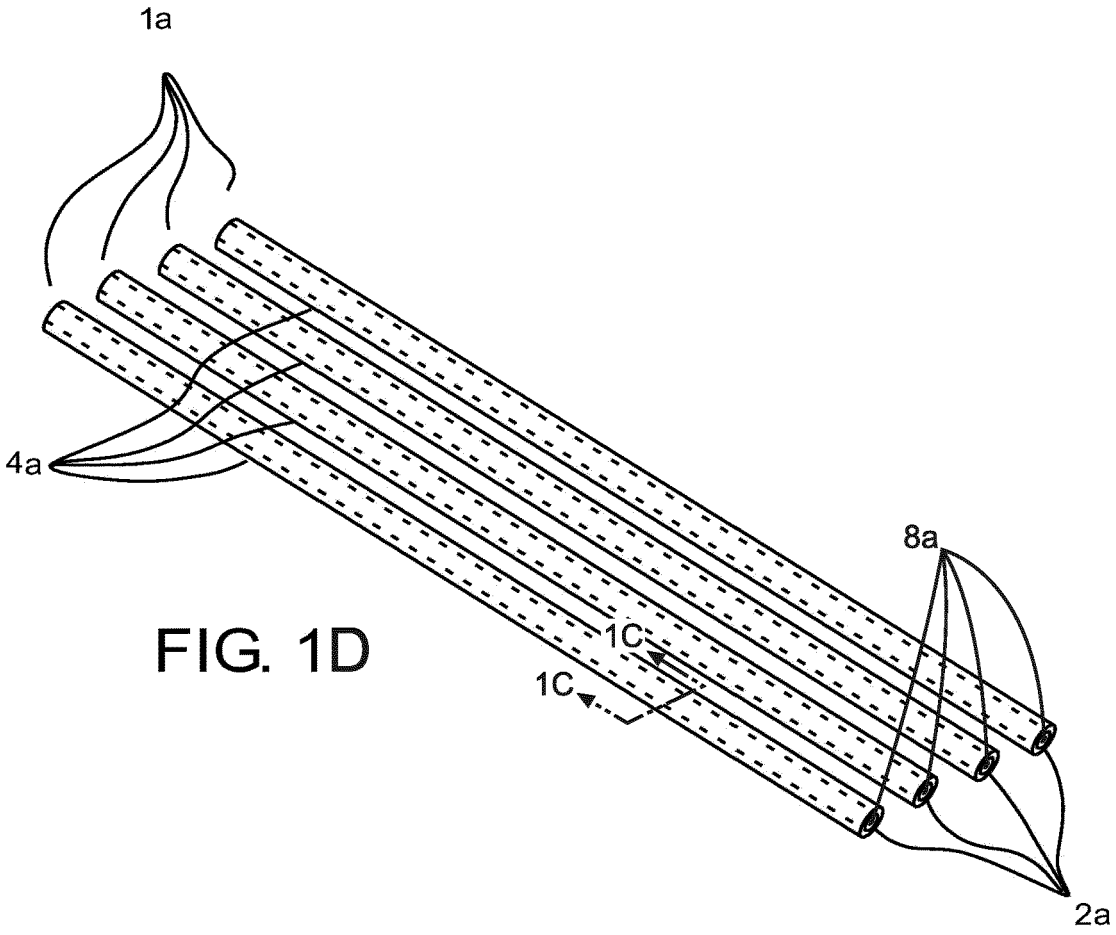


FIG. 1D

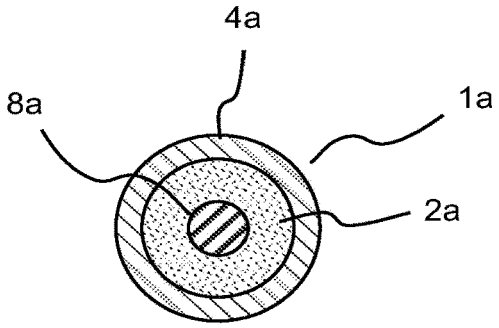


FIG. 1C

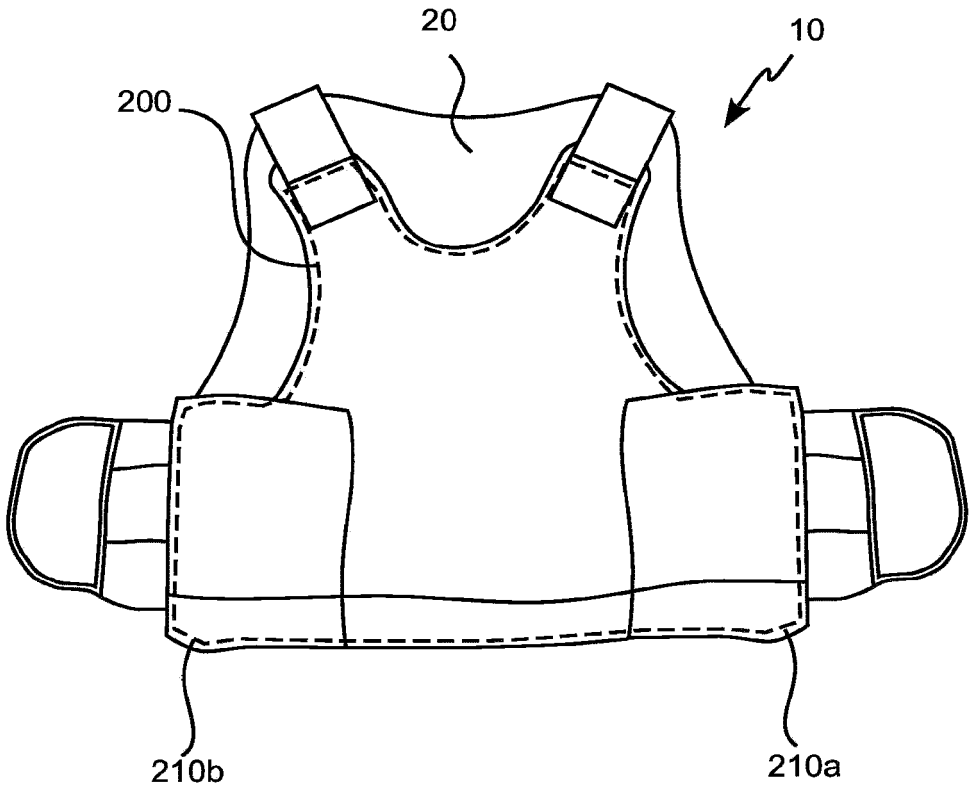


FIG. 2

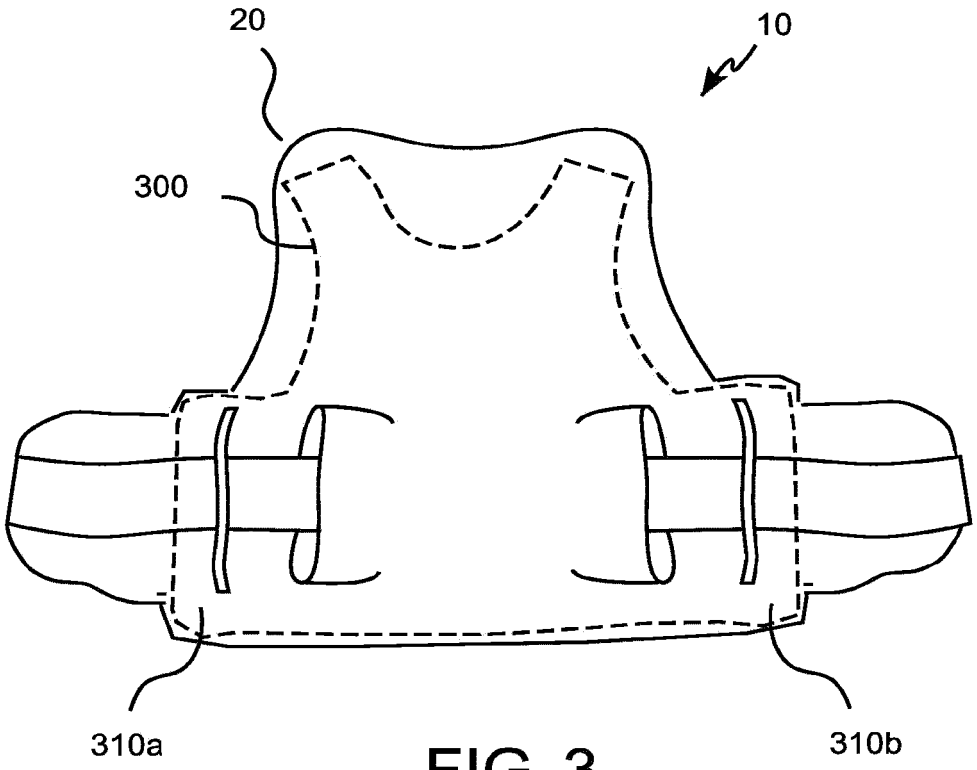


FIG. 3

FIG. 4A

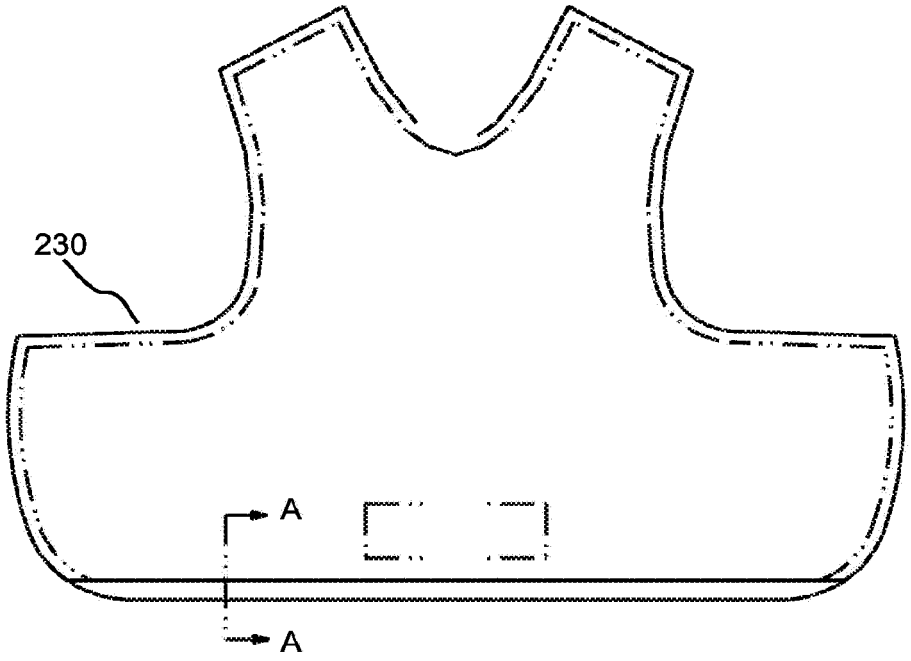
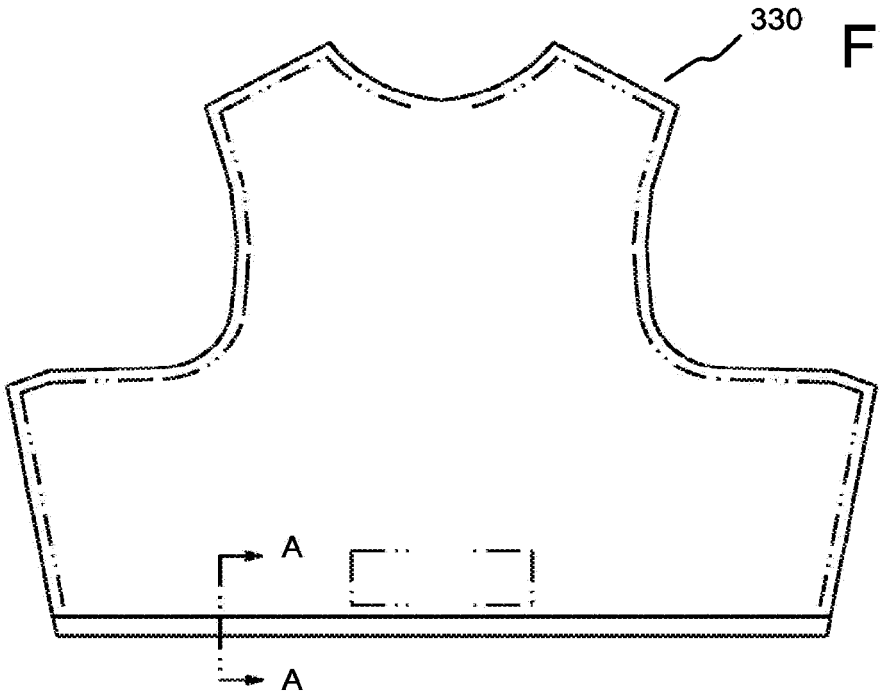


FIG. 4B



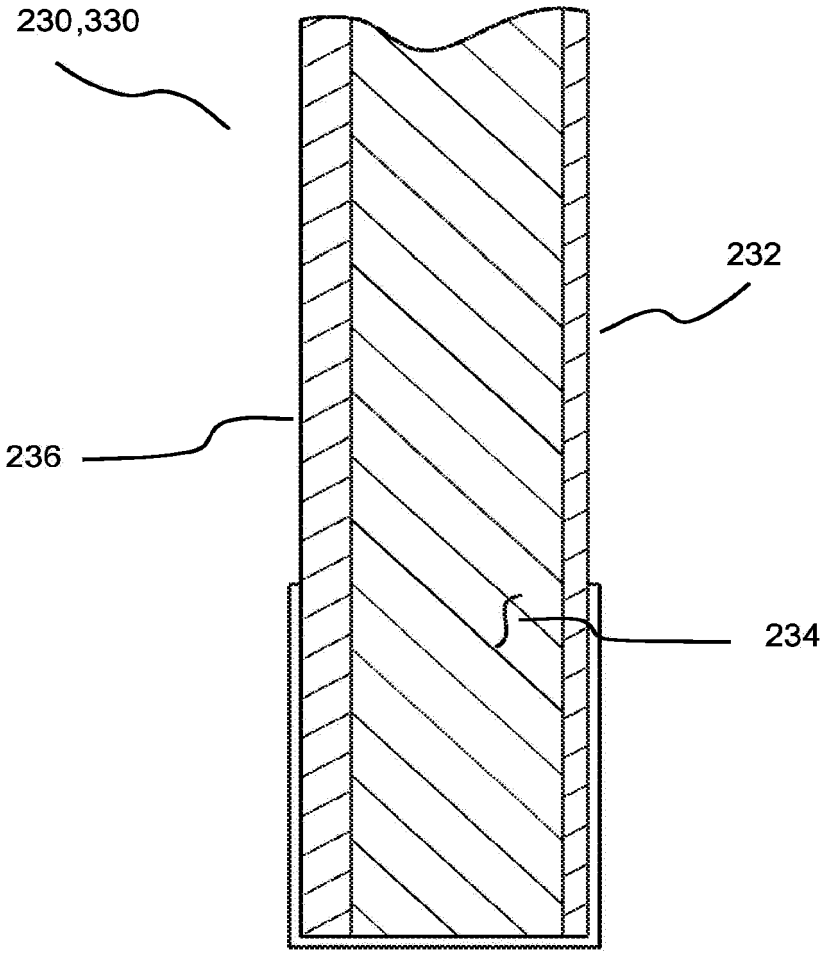


FIG. 4C

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EUROPEAN SEARCH REPORT

Application Number
EP 12 18 3741

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	WO 2008/115636 A2 (DOW GLOBAL TECHNOLOGIES INC [US]; BORELLA RICCO BERNARDO [CH]; BARRY R) 25 September 2008 (2008-09-25) * claims 1-5,11-21,26-33 * * paragraphs [0010], [0024], [0040] - [0048], [0050] - [0055], [0073] - [0084] * * figures 1A-1C * -----	1-6,8, 10,11 7,9-15	INV. F41H5/007 H01B7/02 D01D5/34 D01D5/36 D01F8/04
X Y	WO 2005/000966 A1 (DESIGN BLUE LTD [GB]; GREEN PHILIP [GB]; PALMER RICHARD [GB]) 6 January 2005 (2005-01-06) * claims 33-40 * * figures 1,6-9 * * page 10, lines 15-21 * * page 12, lines 6-17 * * page 12, lines 24-30 * -----	1-5,8, 10,11,14 7,9-15	
X	WO 03/022085 A2 (PLANT DANIEL JAMES [GB]) 20 March 2003 (2003-03-20) * figures 14, 15, 17, 18 * * page 8, lines 10-19 * * page 15, line 4 - page 16, line 28 * * claim 4 * -----	1,8	TECHNICAL FIELDS SEARCHED (IPC) D01D D01F H01B F41H A41D
X A	WO 2008/079584 A1 (DOW GLOBAL TECHNOLOGIES INC [US]; WASSERMAN SCOTT H [US]; COGEN JEFFRE) 3 July 2008 (2008-07-03) * page 3, line 18 - page 5, line 11 * * claims 1-13,18,19 * -----	1-6 7-15	
Y	WO 2010/076257 A2 (PLANT DANIEL JAMES [GB]) 8 July 2010 (2010-07-08) * page 8, line 5 - page 11, line 4 * ----- -/--	7,9-15	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	13 December 2012	Verschuren, Jo

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
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T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

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EUROPEAN SEARCH REPORT

Application Number
EP 12 18 3741

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y	US 2009/094719 A1 (LIM CHEE SENG NORMAN [SG]) 16 April 2009 (2009-04-16) * figure 2 * * paragraphs [0050], [0052] *	7,9-15	
Y	WO 2006/132642 A2 (DU PONT [US]; SAMANT KALIKA RANJAN [US]; SAUER BRYAN BENEDICT [US]; TR) 14 December 2006 (2006-12-14) * page 7, lines 3-30 * * page 9, lines 8-13 * * examples 1,2 *	7,9-15	
A	WO 2004/103231 A1 (UNIV DELAWARE [US]; US ARMY [US]) 2 December 2004 (2004-12-02) * examples 1,2 * * paragraphs [00026] - [00031] *	1-15	
			TECHNICAL FIELDS SEARCHED (IPC)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	13 December 2012	Verschuren, Jo

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 12 18 3741

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13-12-2012

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2008115636 A2	25-09-2008	NONE	
WO 2005000966 A1	06-01-2005	CN 1813032 A	02-08-2006
		EP 1644445 A1	12-04-2006
		GB 2418919 A	12-04-2006
		JP 4884965 B2	29-02-2012
		JP 2007516303 A	21-06-2007
		KR 20060041185 A	11-05-2006
		TW I353819 B	11-12-2011
		US 2007029690 A1	08-02-2007
		US 2010132099 A1	03-06-2010
		WO 2005000966 A1	06-01-2005
WO 03022085 A2	20-03-2003	AT 468769 T	15-06-2010
		EP 1489934 A2	29-12-2004
		ES 2346743 T3	20-10-2010
		US 2004171321 A1	02-09-2004
		US 2010086747 A1	08-04-2010
		WO 03022085 A2	20-03-2003
WO 2008079584 A1	03-07-2008	CA 2671366 A1	03-07-2008
		CN 101563733 A	21-10-2009
		EP 2102873 A1	23-09-2009
		JP 2010514143 A	30-04-2010
		TW 200901232 A	01-01-2009
		US 2010027948 A1	04-02-2010
		WO 2008079584 A1	03-07-2008
WO 2010076257 A2	08-07-2010	EP 2361023 A2	31-08-2011
		US 2012021167 A1	26-01-2012
		WO 2010076257 A2	08-07-2010
US 2009094719 A1	16-04-2009	SG 152075 A1	29-05-2009
		US 2009094719 A1	16-04-2009
WO 2006132642 A2	14-12-2006	BR PI0511409 A	04-12-2007
		CA 2571371 A1	14-12-2006
		CN 101484773 A	15-07-2009
		EP 1787083 A2	23-05-2007
		JP 4787251 B2	05-10-2011
		JP 2008503663 A	07-02-2008
		KR 20070083464 A	24-08-2007
		US 2005282007 A1	22-12-2005
		US 2005282450 A1	22-12-2005
		WO 2006083312 A1	10-08-2006
		WO 2006132642 A2	14-12-2006

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 12 18 3741

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

13-12-2012

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2004103231 A1	02-12-2004	CA 2526291 A1	02-12-2004
		EP 1633293 A1	15-03-2006
		US 2005266748 A1	01-12-2005
		US 2006234577 A1	19-10-2006
		US 2010269236 A1	28-10-2010
		WO 2004103231 A1	02-12-2004

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82