2007-09-20 CN 200710122028

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2008-03-12 CN101140151A Application

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Description

translated from Chinese

将液态性材料按样板裁剪成片，用8片缝合在一起制成防弹防刺片，装入内胆罩中密封，再将内胆在风衣内侧用纽扣挂接方式和其连接即制成时装款式的液态性材料的防弹防刺服。

液态性材料的防弹防刺服所属技术领域本发明涉及一种功能性服装，具体涉及一种防弹防刺服装。 Anti-ballistic armor skilled liquid material in the present invention relates to a functional clothing, in particular to a stab and ballistic resistant garment. 背景技术当前防刺服或防弹衣由钢板、铝合金板整板制造，不能弯曲身体，也有用钢板、铝合金板小块做成鱼鳞状，身体只能微微弯曲，却有重量大的缺点。 BACKGROUND ART stab-resistant clothing or body armor plate, the entire plate made from aluminum alloy sheet, the body can not be bent, the steel sheet is also useful, scaly aluminum alloy plate made small, only slightly curved body, there are disadvantages of a large weight. 也有采用芳纶纤维布、高强聚乙烯布制造的防弹衣，可防子弹，但也防不了刀刺。 There is also an aramid fiber cloth, high-strength polyethylene fabric manufactured body armor, bullet proof can be, but not anti-stabbed. 例如：用36层芳纶布制造的防弹衣可防54式手枪子弹的弹击，却防不了24焦耳能量的刀刺。 For example: a body armor layer 36 may be fabricated Kevlar cloth 54 preventing the tapping of pistol bullets, but not anti-knife stab 24 joules of energy. 发明内容本发明的目的是提供一种液态性材料又轻又薄的防弹防刺服，其特征在于，具有：防弹防刺材料，其由用具有剪切增稠特性的硬质纳米粒子悬浮液制成的剪切增稠液体浸渍的高强度纤维机织物、针织物、非织造织物单层或多层叠加制成；外罩，其内侧或夹层可以和防弹防刺材料

present patent is: 1, do not show shear thickening fluid barrier properties especially at room temperature, Stab proof material is usually very soft close, taking

性很强。 Strong. 2、 防弹防刺材料一旦遇到冲击，剪切增稠液体中的硬质纳米粒子便成簇聚集，使得防弹防刺材料变硬连锁在一起发挥阻隔防护作用，防护性能很强。 2, Stab proof material in the event of impact, the hard nanoparticles in shear thickening fluid will be aggregated clusters, so that the material hardens chain Stab proof barrier together play a protective role, strong protection performance. 3、 部分解决了自古以来服用性和防护性能的之间的永恒矛盾。 3, a partial solution to the eternal conflict between ancient and taking protective properties. 4、 浸渍了剪切增稠液体的防护材料比没浸渍的同样材料的防护性能要高很多，所以可以用更薄的防护材料达到同样的防护性能，使得整个服装重量减轻、厚度变小、更柔软贴身。 4, the protective material impregnated with the shear thickening fluid barrier properties than did the same impregnation material to be much higher, it is possible to use a thinner protective materials to achieve the same protective properties, so that the entire garment weight, small thickness, and more soft close. 附图说明本发明无附图。 BRIEF DESCRIPTION OF DRAWINGS The invention no. 具体实施方式以下对本发明进步说明，但是并不限定于此保护范围。 DETAILED DESCRIPTION The following description of the present invention into ho, the scope of protection is not limited thereto. 实施例1:配制剪切增稠浸渍液，配方如下（重量比）：纳米级球形二氧化硅粒子60%聚乙二醇20% 乙二醇10% 乙醇10% 将芳给1414纤维机织布浸渍在剪切增稠浸渍液中，使其充分吸收剪切增稠浸渍液，浸渍后将溶剂乙醇烘出，即制成液态性防弹防刺材料。 Example 1: preparation shear thickening immersion fluid, formulated as follows (weight ratio): nano-sized spherical silica particles of 60% polyethylene glycol 20% Ethylene glycol 10% Ethanol 10% The aryl woven fiber 1414 to immersed in the impregnating solution shear thickening, shear thickening sufficiently absorb the impregnation solution, the impregnation solvent of ethanol after bake-out, i.e., made of a liquid stab proof material. 将液态性材料按样板裁剪成片，用18片缝合在一起制成防弹防刺片，装入内胆罩中密封，再装入已制好的外罩中即制成背心马甲式液态性材料的防弹防刺服。 The liquid material is cut into pieces by a model, made by sewing together 18 Stab proof sheet, sealing the cover liner was charged, and then into already ready-made enclosure made vest vest i.e. liquid materials of formula stab proof clothing. 实施例2:配制剪切增稠浸渍液，配方如下（重量比）：纳米级球形硅粒子40%聚乙二醇30%乙二醇20%乙醇10%将芳纶1414纤维机织布浸渍在剪切增稠浸渍液中，使其充分吸收剪切增稠浸渍液，浸渍后将溶剂乙醇烘出，即制成液态性防弹防刺材料。 Example 2: preparation shear thickening immersion fluid, formulated as follows (weight ratio): nanoscale spherical silicon particles 40% Polyethylene glycol 30% ethylene glycol 20% ethanol 10% aramid fiber woven fabric was immersed in 1414 shear thickening impregnating solution, so as to fully absorb the shear thickening fluid impregnation, after impregnation solvent such as ethanol bake-out, i.e., made of a liquid stab proof material. 将液态性材料按样板裁剪成片，用16片缝合在一起制成防弹防刺片，装入内胆罩中密封，再装入已制好的外罩中即制成背心马甲式液态性材料的防弹防刺服。 The liquid material is cut into pieces by a model, made by sewing together 16 Stab proof sheet, sealing the cover liner was charged, and then into ready-made enclosure made vest vest i.e. liquid materials of formula The stab and bullet-proof clothing. 实施例3:配制剪切增稠浸渍液，配方如下

：纳米级不规则形聚合物粒子35% 聚乙二醇23% 异丙醇15% 乙醇27% 将高强度尼龙针织物浸渍在剪切增稠浸渍液中，使其充分吸收剪切增稠浸渍液，浸渍后将溶剂乙醇烘出，即制成液态性防弹防刺材料。 Example 6: preparation shear thickening immersion fluid, formulated as follows (weight ratio): irregular nanoscale polymer particles 35% 23% Polyethylene glycol 15% ethanol 27% isopropanol impregnated high strength nylon fabric in the shear thickening impregnating solution, so as to fully absorb the shear thickening fluid impregnation, after impregnation solvent such as ethanol bake-out, i.e., made of a liquid stab proof material. 将液态性材料按样板裁剪成片，用32片缝合在一起制成防弹防刺片，装入内胆罩中密封，再将内胆在皮装内侧和其连接即制成时装款式液态性材料的防弹防刺服。 The liquid material is cut into pieces by a model, made by sewing together 32 Stab proof sheet, sealing the cover liner was charged, and then the inner liner is connected in leather i.e., a liquid material made of fashions the stab and bulletproof clothing.

Claims (6)

translated from Chinese

1、一种液态性材料的防弹防刺服，其特征在于，具有：防弹防刺材料，其由用具有剪切增稠特性的硬质纳米粒子悬浮液制成的剪切增稠液体浸渍的高强度纤维机织物、针织物、非织造织物单层或多层叠加制成；外罩，其内侧或夹层可以和防弹防刺材料连接或嵌入的基本样式的各种工作服、特种服装、时装、衬衫、茄克衫、马甲、毛编织服装和皮装。

1、一种液态性材料的防弹防刺服，其特征在于，具有：防弹防刺材料，其由用具有剪切增稠特性的硬质纳米粒子悬浮液制成的剪切增稠液体浸渍的高强度纤维机织物、针织物、非织造织物单层或多层叠加制成；外罩，其内侧或夹层可以和防弹防刺材料连接或嵌入的基本样式的各种工作服、特种服装、时装、衬衫、茄克衫、马甲、毛编织服装和皮装。 1, a liquid material is anti-ballistic armor, comprising: a stab and ballistic resistant material impregnated with a shear thickening fluid made of a hard nanoparticle suspension having a shear thickening properties high strength fiber woven fabric, knitted fabric, nonwoven fabric made of single or multiple superposed; housing, the inside or interlayer may stab and ballistic resistant material connected to or embedded in various styles substantially uniforms, special clothing, fashion, shirts , jackets, vests, wool knit garments and leather.

2、根据权利要求1所述的硬质纳米粒子，其特征在于，硬质纳米粒子的形状可为球形、块形、片形、不规则形，其中优选球形。 2. The hard nanoparticles according to claim 1, wherein the shape of the hard nanoparticles may be spherical, block-shaped, plate-shaped, irregular-shaped, wherein preferably spherical.

3、根据权利要求1所述的硬质纳米粒子，其特征在于，硬质纳米球型粒子的材质可为二氧化硅、硅、无机材料、金属、碳酸钙、PVC、塑料、磁性材料、聚合物，其中优选二氧化硅、硅。 3, according to the hard nanoparticles according to claim 1, wherein the hard spherical nano-particles may be made of silicon dioxide, silicon, an inorganic material, a metal, calcium carbonate, PVC, plastic, magnetic material, polymeric , wherein preferably silica, silicon.

CN102717668A * 2012-04-27 2012-10-10 张国清 Inner-tire active safety air bag for separate explosion-proof tire

CN102733175A * 2011-04-08 2012-10-17 江南大学 Multiple dispersed phase flame retardant shear thickening fluid, its preparation method and application thereof

CN102899894A * 2012-05-30 2013-01-30 杭州师范大学 Preparation method and use of shear thickening fluid

CN103422341A * 2012-05-15 2013-12-04 常熟宝盾高性能纤维材料制品有限公司 Preparation method of shear thickening fluid

CN104913688A * 2015-06-11 2015-09-16 浙江理工大学 Liquid flexible bulletproof vest and production method thereof

US9670334B2 2014-08-26 2017-06-06 Industrial Technology Research Institute Shear thickening formulation and composite material employing the same

Family To Family Citations

* Cited by examiner, † Cited by third party, ‡ Family to family citation

Similar Documents

Publication Publication Date Title

US5885912A 1999-03-23 Protective multi-layered liquid retaining composite

US6026509A 2000-02-22 Ballistic resistant garment with multi-panel radial securement stitching

US20020069453A1 2002-06-13 Firefighter garment thermal liner material including hydrophobic fibers

US7010811B1 2006-03-14 Lightweight soft body-armor product

Mukhopadhyay et al. 2008 A review on designing the waterproof breathable fabrics part I: fundamental principles and designing aspects of breathable fabrics

US5880042A 1999-03-09 Clothing for protection against stab and bullet wounds

US6846758B2 2005-01-25 Ballistic fabric laminates

US8176830B1 2012-05-15 Ballistic shield

US5536553A 1996-07-16 Protective fabric comprising calendered sub-plies of woven fabric joined together by stitching

US20050266748A1 2005-12-01 Advanced body armor utilizing shear thickening fluids

US6371977B1 2002-04-16 Protective multi-layered liquid retaining composite

CN101181661A 2008-05-21 Multifunctional ventilating type protection material and preparation method thereof

WO1991006823A2 1991-05-16 Ceramic armor reinforced with high-strength fibers and ballistic resistant articles formed from said armor

B32B15/04 Layered products comprising a layer of metal comprising metal as the main or only constituent of a layer, which is next to another layer of the same or of a different material

B32B15/08 Layered products comprising a layer of metal comprising metal as the main or only constituent of a layer, which is next to another layer of the same or of a different material of synthetic resin

B32B15/095 Layered products comprising a layer of metal comprising metal as the main or only constituent of a layer, which is next to another layer of the same or of a different material of synthetic resin comprising polyurethanes

B PERFORMING OPERATIONS; TRANSPORTING

B32 LAYERED PRODUCTS

B32B LAYERED PRODUCTS, i.e. PRODUCTS BUILT-UP OF STRATA OF FLAT OR NON-FLAT, e.g. CELLULAR OR HONEYCOMB, FORM

B32B27/00 Layered products comprising a layer of synthetic resin

B32B27/12 Layered products comprising a layer of synthetic resin next to a fibrous or filamentary layer

B PERFORMING OPERATIONS; TRANSPORTING

B32 LAYERED PRODUCTS

B32B LAYERED PRODUCTS, i.e. PRODUCTS BUILT-UP OF STRATA OF FLAT OR NON-FLAT, e.g. CELLULAR OR HONEYCOMB, FORM

B32B27/00 Layered products comprising a layer of synthetic resin

B32B27/18 Layered products comprising a layer of synthetic resin characterised by the use of special additives

B PERFORMING OPERATIONS; TRANSPORTING

B32 LAYERED PRODUCTS

B32B LAYERED PRODUCTS, i.e. PRODUCTS BUILT-UP OF STRATA OF FLAT OR NON-FLAT, e.g. CELLULAR OR HONEYCOMB, FORM

B32B27/00 Layered products comprising a layer of synthetic resin

B32B27/40 Layered products comprising a layer of synthetic resin comprising polyurethanes

B PERFORMING OPERATIONS; TRANSPORTING

B32 LAYERED PRODUCTS

B32B LAYERED PRODUCTS, i.e. PRODUCTS BUILT-UP OF STRATA OF FLAT OR NON-FLAT, e.g. CELLULAR OR HONEYCOMB, FORM

B32B3/00 Layered products comprising a layer with external or internal discontinuities or unevennesses, or a layer of non-planar form ; Layered products having particular features of form

B32B3/26 Layered products comprising a layer with external or internal discontinuities or unevennesses, or a layer of non-planar form ; Layered products having particular features of form

B32 LAYERED PRODUCTS

B32B LAYERED PRODUCTS, i.e. PRODUCTS BUILT-UP OF STRATA OF FLAT OR NON-FLAT, e.g. CELLULAR OR HONEYCOMB, FORM

B32B9/00 Layered products comprising a particular substance not covered by groups B32B11/00 - B32B29/00

B32B9/04 Layered products comprising a particular substance not covered by groups B32B11/00 - B32B29/00 comprising such particular substance as the main or only constituent of a layer, which is next to another layer of the same or of a different material

B32B9/041 Layered products comprising a particular substance not covered by groups B32B11/00 - B32B29/00 comprising such particular substance as the main or only constituent of a layer, which is next to another layer of the same or of a different material of metal

B PERFORMING OPERATIONS; TRANSPORTING

B32 LAYERED PRODUCTS

B32B LAYERED PRODUCTS, i.e. PRODUCTS BUILT-UP OF STRATA OF FLAT OR NON-FLAT, e.g. CELLULAR OR HONEYCOMB, FORM

B32B9/00 Layered products comprising a particular substance not covered by groups B32B11/00 - B32B29/00

B32B9/04 Layered products comprising a particular substance not covered by groups B32B11/00 - B32B29/00 comprising such particular substance as the main or only constituent of a layer, which is next to another layer of the same or of a different material

B32B9/045 Layered products comprising a particular substance not covered by groups B32B11/00 - B32B29/00 comprising such particular substance as the main or only constituent of a layer, which is next to another layer of the same or of a different material of synthetic resin

B PERFORMING OPERATIONS; TRANSPORTING

B32 LAYERED PRODUCTS

B32B LAYERED PRODUCTS, i.e. PRODUCTS BUILT-UP OF STRATA OF FLAT OR NON-FLAT, e.g. CELLULAR OR HONEYCOMB, FORM

B32B9/00 Layered products comprising a particular substance not covered by groups B32B11/00 - B32B29/00

B32B9/04 Layered products comprising a particular substance not covered by groups B32B11/00 - B32B29/00 comprising such particular substance as the main or only constituent of a layer, which is next to another layer of the same or of a different material

B32B9/047 Layered products comprising a particular substance not covered by groups B32B11/00 - B32B29/00 comprising such particular substance as the main or only constituent of a layer, which is next to another layer of the same or of a different material made of fibres or filaments

F MECHANICAL ENGINEERING; LIGHTING; HEATING; WEAPONS; BLASTING

F41 WEAPONS

B PERFORMING OPERATIONS; TRANSPORTING

B32 LAYERED PRODUCTS

B32B LAYERED PRODUCTS, i.e. PRODUCTS BUILT-UP OF STRATA OF FLAT OR NON-FLAT, e.g. CELLULAR OR HONEYCOMB, FORM

B32B2264/00 Composition of particles which form a particulate layer or are present as additives

B32B2264/10 Inorganic particles

B PERFORMING OPERATIONS; TRANSPORTING

B32 LAYERED PRODUCTS

B32B LAYERED PRODUCTS, i.e. PRODUCTS BUILT-UP OF STRATA OF FLAT OR NON-FLAT, e.g. CELLULAR OR HONEYCOMB, FORM

B32B2266/00 Composition of foam

B32B2266/04 Inorganic

B32B2266/045 Metal

B PERFORMING OPERATIONS; TRANSPORTING

B32 LAYERED PRODUCTS

B32B LAYERED PRODUCTS, i.e. PRODUCTS BUILT-UP OF STRATA OF FLAT OR NON-FLAT, e.g. CELLULAR OR HONEYCOMB, FORM

B32B2307/00 Properties of the layers or laminate

B32B2307/30 Properties of the layers or laminate having particular thermal properties

B32B2307/306 Resistant to heat

B32B2307/3065 Flame resistant or retardant, fire resistant or retardant

B PERFORMING OPERATIONS; TRANSPORTING

B32 LAYERED PRODUCTS

B32B LAYERED PRODUCTS, i.e. PRODUCTS BUILT-UP OF STRATA OF FLAT OR NON-FLAT, e.g. CELLULAR OR HONEYCOMB, FORM

B32B2307/00 Properties of the layers or laminate

B32B2307/50 Properties of the layers or laminate having particular mechanical properties

B32B2307/54 Yield strength; Tensile strength

B PERFORMING OPERATIONS; TRANSPORTING

B32 LAYERED PRODUCTS

B32B LAYERED PRODUCTS, i.e. PRODUCTS BUILT-UP OF STRATA OF FLAT OR NON-FLAT, e.g. CELLULAR OR HONEYCOMB, FORM

B32B2307/00 Properties of the layers or laminate

Y10T TECHNICAL SUBJECTS COVERED BY FORMER US CLASSIFICATION

Y10T428/00 Stock material or miscellaneous articles

Y10T428/24 Structurally defined web or sheet [e.g., overall dimension, etc.]

Y10T428/24273 Structurally defined web or sheet [e.g., overall dimension, etc.] including aperture

Y10T428/24322 Composite web or sheet

Y10T428/24331 Composite web or sheet including nonapertured component

View 27 more classifications

Hide more classifications

WO2010123593A2

WO Application

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Other languages

French

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Original Assignee

Trigon Holdings, Lc

Priority date

The priority date is an assumption and is not a legal conclusion.
Google has not performed a legal analysis and makes no representation as to the accuracy of the date listed.

2009-01-13

Family: US (1)**WO (1)**

Date App/Pub Number Status

The legal status is an assumption and is not a legal conclusion.
Google has not performed a legal analysis and makes no representation as to the accuracy of the status listed.

2010-01-13 PCT/US2010/020930

expires

2010-10-28 WO2010123593A2 Application

2011-04-14 WO2010123593A3 Application

[0005] In view of the foregoing, new lightweight materials having enhanced ballistic protection for both personal and vehicular use would be of substantial benefit in both military and civilian applications. Not only would such materials offer improved ballistic protection, but they would also provide improved wearer comfort and improved vehicular performance over heavier materials currently in use. SUMMARY

[0006] In various embodiments, laminate materials having a first layer of a dilatant compound, a second layer of a ceramic material and a third layer of a strike face material are described herein. The second layer is between the first layer and the third layer.

[0007] In other various embodiments, laminate materials of the present disclosure have a first layer of a dilatant compound and a polymer fiber component, a second layer of a ceramic material and a third layer of a strike face material. The polymer fiber component is arranged in sub-layers within the first layer. The strike face material includes at least one metal underlayer, a polymer material, and a nanomaterial dispersed in the polymer material. The at least one metal underlayer is patterned with a plurality of holes. The polymer material fills at least a portion of the plurality of holes. The second layer is interposed between the first layer and the third layer.

[0008] In other various embodiments, dilatant compounds are described herein. The dilatant compounds include a silicone fluid and a nanomaterial dispersed in the silicone fluid. The nanomaterial is fltnctionalized with at least one süane coupling agent. In some embodiments, the nanomaterial is HALLO YSITE nanotubes.

[0009] The foregoing has outlined rather broadly the features of the present disclosure in order that the detailed description that follows may be better understood. Additional features and advantages of the disclosure will be described hereinafter, which form the subject of the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] For a more complete understanding of the present disclosure, and the advantages thereof, reference is now made to the following descriptions to be taken in conjunction with the accompanying drawings describing specific embodiments of the disclosure, wherein:

[0011] FIGURE 1 shows a schematic of an illustrative response of a dilatant compound to shear conditions;

[0012] FIGURE 2 shows an illustrative electron micrograph of H ALLO YSITE nanotubes; [0013] FIGURE 3 shows an illustrative embodiment of a metal underlayer used in strike faces of the present disclosure;

[0014] FIGURE 4 shows an illustrative electron micrograph of HALLO YSITE nanotubes filled with resorcinol diphenyl phosphate (RDP);

[0015] FIGURE 5 shows an illustrative schematic of a laminate material produced according to one embodiment of the present disclosure; and

[0016] FIGURES 6 A - 6D show illustrative images of a laminate material of the present disclosure following ballistics testing. FIGURE 6A shows the impact zone in the thermoplastic polyurethane/HALLO YSITE layer on the exterior of the strike face. FIGURE 6B shows the impact zone in the thermoplastic polyurethane layer on the interior of the strike face. FIGURE 6C shows the impact zone at the metal underlayer of the strike face. FIGURE 6D shows the impact of the projectile in the high-molecular weight polyethylene layers after yawing.

R^1, R^2 and R^3 can be selected independently from hydrogen, hydroxyl, thiol, alkyl and cycloalkyl groups, alkenyl and cycloalkenyl groups, alkynyl and cycloalkynyl groups, aryl and heteroaryl groups, heterocyclic groups, amines, amides, esters, ethers, epoxides, and combinations thereof.

[0025J As used herein, the term "polyurethanes" will be used to refer to any of polyurethane polymers, polyurea polymers, and hybrid polyurethane/polyurea polymers. One of ordinary skill in the art will recognize that any of the various embodiments herein utilizing polyurethane polymers may be practiced equivalently using polyurea polymers, hybrid polyurethane/polyurea polymers, or other thermoplastic polymers known in the art having suitable properties for the chosen application. Thermoplastic polyurethanes are particularly advantageous for practicing the various embodiments of the present disclosure due to their ease of use in forming laminate materials. In terms of performance, thermoplastic polyurethane films represent a desirable compromise between cost and performance, as they are easily cut and handled for processing by lay-up and autoclave processing technology. Further, thermoplastic polyurethane coatings offer high curing rates, a wide range of operating temperature, ballistic resistance, chemical resistance and imperviousness to chemicals. These properties are among those that make thermoplastic polyurethanes well suited for use in the laminate materials of the present disclosure due to their suitability for use in a wide range of field conditions. Further, due to their amenability to lay-up processing, the thermoplastic polyurethanes may be evenly distributed between layers. In contrast, epoxies, resins or wet chemistry binders may not be evenly distributed, thereby leading to potential impact failure.

[0026] In some embodiments, thermoplastic polyurethanes may be used to coat the laminate materials of the present disclosure. In coating applications, the thermoplastic polyurethanes may again include a nanomaterial filler. Nanomaterial fillers advantageously confer strength to the coatings. Use of the thermoplastic polyurethanes as a coating or as a laminating material between layers may also provide protection from shock and vibration, particularly for the ceramic material. Alternative coating materials include, without limitation, epoxy polymers, silicone rubber, and other thermoplastic polymers. [0027] In any of the various embodiments of the present disclosure, the thermoplastic polyurethanes may possess the ability to covalently bind to suitably functionalized organic and inorganic materials. Thermoplastic polyurethanes capable of such covalent bonding are now commercially available from Huntsman Polyurethanes. In some embodiments, the thermoplastic polyurethanes may be functionalized with a silane coupling agent in order to achieve the capability for covalent bonding. Covalent bonding advantageously increases the compatibility between layers composed of different materials and thereby strengthens the laminate materials in various embodiments of the present disclosure.

[0028] In various embodiments of the laminate materials of the present disclosure, the dilatant compound, the ceramic material and the strike face material are all silane functionalized with at least one silane coupling agent. As described hereinabove, silane functionalization provides the opportunity for cross-linking to strengthen the laminate materials. Further, as described hereinbelow, silane functionalization may strengthen individual components of the laminate materials by correcting defects in their structure.

[0029] In various embodiments, the ceramic material of the laminate material's second layer may be, for example, boron carbide, silicon carbide, cubic boron nitride and various combinations thereof. Cubic boron nitride, in particular, offers the potential to form thinner laminate layers while maintaining mechanical strength. A commercially viable route to cubic boron nitride is now available. In various embodiments, cubic boron nitride may be synthesized by the reaction of boron with carbon nitride at pressures greater than about 9 GPa. It is believe that cubic boron nitride may have mechanical properties that surpass those of diamond.

[0033] As shown in Table 1, SPECTRA 2000 fibers are about 30% lighter than KEVLAR, which is currently used in ballistics applications and offers the opportunity for weight reduction in armor applications as a result. In addition to weight reduction, SPECTRA 2000 and other ultrahigh molecular weight polyethylene fibers offer the potential for improved ballistic protection. For example, one of the more advantageous properties of ultra-high molecular weight polyethylene fibers is the ability to withstand high load strain weight velocities without failure. This feature is particularly relevant for its use in high velocity ballistics applications, such as those described in the present disclosure.

[0034] In some embodiments, the polymer fibers are arranged in a plurality of sub-layers within the first layer. In some embodiments, each of the plurality of sub-layers within the first layer is laminated to one another through a plurality of thermoplastic polyurethane sub-layers. In some embodiments, the polymer fibers are covalently bonded to the plurality of thermoplastic polyurethane sub-layers. For example, in some embodiments, the polymer fibers may be functionalized with a silane coupling agent and cross-linked with the thermoplastic polyurethane sub-layers. In some embodiments, the dilatant compound coats the polymer fibers. In some embodiments, the thermoplastic polyurethane sub-layers contain HALLOYSITE or another nanomaterial in order to increase puncture resistance.

[0035] Dilatant compounds may be thought of as non-Newtonian fluids and are an example of "smart" materials that can sense and respond to changes in their environment. Under normal conditions, the molecules of a dilatant compound are weakly bonded and can move around with ease, but the pressure shock from an impact results in strengthening of the chemical bonds, thereby locking the molecules into place and hardening the material. Once the impact force dissipates, the bonds weaken and the material returns to its flexible state. Hardening of the dilatant compound prevents a projectile from penetrating the fluid in its hardened state. FIGURE 1 shows a schematic of an illustrative response of a dilatant compound to shear conditions.

[0042] Furthermore, in various embodiments, the HALLOY S ITE nanotubes may be functionalized with silane coupling agents in order to enhance their compatibilization with and dispersion into silicone fluids. In some embodiments, the HALLO YSITE nanotubes may further be cross-linked with the silicone fluid after being functionalized with the silane coupling agents. Furthermore, HALLOYSITE nanotubes are able to hydrogen bond to polymer substrates, strengthening the laminate materials of the present disclosure and conferring additional puncture resistance thereto.

[0043] HALLOYSITE nanotubes are advantageous over other nanoclay materials for dispersal in silicone-based dilatant compounds and other polymer materials. For example, relative to montmorillonite, HALLOYSITE nanotubes have a much lower cation exchange capacity and reduced swelling upon wetting. These properties ease the dispersion ability of the HALLOYSITE nanotubes. Furthermore, the tubular shape and inner lumen diameter of HALLOYSITE nanotubes are amenable for being filled with various additives. For example, in some embodiments of the present disclosure the dilatant compound may fill the lumen of the HALLOYSITE nanotubes. In other embodiments, additives such as, for example, UV stabilizers or corrosion inhibitors may fill the lumen of the HALLOYSITE nanotubes. Without being bound by theory of mechanism, Applicants believe that filling of the lumen may also lead to improved puncture resistance of the laminate materials of the present disclosure.

[0044] In various embodiments of the present disclosure, the dilatant compound may be intercalated into a yarn or a fabric. Since dilatant compounds maintain their properties down to micro -size scale and lower, application to very small surface areas such as yarns and fabrics becomes possible. Although dilatant compounds have desirable compression and shear response, they typically have poor tensile strength. Therefore, in various embodiments of the present disclosure, the dilatant compound is combined with a fiber component (e.g., polymer fibers) to yield a high tensile strength composite material having impact and puncture resistance. For example, in various embodiments of the present disclosure, dilatant compounds may be combined with KEVLAR or ultra-high molecular weight polyethylene fibers. [0045] In various embodiments, a strike face material forms the third layer of the laminate materials of the present disclosure. In various embodiments, strike faces of the present disclosure are a composite material formed from at least one metal underlayer and a polymer material. In some embodiments, the at least one metal underlayer is patterned with a plurality of holes in, for example, a "honeycomb" arrangement. FIGURE 3 shows an illustrative embodiment of a metal underlayer used in strike faces of the present disclosure. In various embodiments, the at least one metal underlayer is silane functionalized with at least one silane coupling agent.

[0046] In various embodiments of the laminate materials, a polymer material coats the at least one metal underlayer. In some embodiments, the polymer material fills at least a portion of the plurality of holes in the metal underlayer. In some embodiments, the polymer material further includes a nanomaterial filler dispersed in the polymer material. Hence, in various embodiments, at least a portion of the holes in the metal underlayer are filled with both polymer material and nanomaterial filler. In some embodiments, the polymer material is a polyurea or polyurethane (e.g., a thermoplastic polyurethane). In some embodiments, the polymer material is spray coated on to the metal underlayer.

[0047] In some embodiments, nanomaterial fillers for the polymer materials of the strike face include, for example, HALLO YSITE nanotubes, carbon nanotubes and combinations thereof. Carbon nanotubes in the polymer material of the strike face can include without limitation, single-wall carbon nanotubes and carbon nanotubes having more than one wall (e.g., multi-wall carbon nanotubes).

component of the strike face, for example, in a polymer material coating the metal underlayer. As noted above, HALLOYSITE nanotubes can be both filled in their lumen and coated with various additives. FIGURE 4 shows an illustrative electron micrograph of HALLOYSITE nanotubes filled with resorcinol diphenyl phosphate (RDP), a flame retardant. As shown in FIGURE 4, the HALLOYSITE nanotubes are both filled and surface coated with the RDP. Inclusion of RDP with the HALLOYSITE nanotubes confers beneficial flame retardancy to polymer composites produced therefrom. For example, poly(methylmethacrylate) (PMMA) treated with decabromodiphenyl ether and antimony oxide fails the UL-94 VO flame retardancy test at 1.5 mm thickness. However, when a 5% loading of HALLOYSITE nanotubes treated with RDP is dispersed in the PMMA, the resultant composite material passes the UL-94 VO test. Normally, inclusion of RDP in a polymer would significantly reduce the observed modulus. However, when RDP is included with HALLOYSITE nanotubes, the modulus may be maintained while still conferring flame retardancy. Hence, in some embodiments, polymer coatings of the strike face may be flame retardant, as well as providing ballistic protection, while maintaining flexibility and abrasion resistance. Such flame retardancy may also be beneficial for field use of the laminate materials described herein.

[0054] In various embodiments, laminate materials of the present disclosure have a first layer of a dilatant compound and a polymer fiber component, a second layer of a ceramic material and a third layer of a strike face material. The polymer fiber component is arranged in sub-layers within the first layer. The strike face material includes at least one metal underlayer, a polymer material, and a nanomaterial dispersed in the polymer material. The at least one metal underlayer is patterned with a plurality of holes. The polymer material fills at least a portion of the plurality of holes. The second layer is interposed between the first layer and the third layer. In some embodiments, at least the metal underlayer, the polymer material, the nanomaterial and the ceramic material are silane functionalized.

[0055] In some embodiments, the first layer further includes HALLO YSITE nanotubes dispersed in the dilatant compound. In some embodiments, the dilatant compound is a silicone fluid cross- linked with at least one silane coupling agent, hi such embodiments, the HALLOYSITE nanotubes are silane functionalied with the at least one silane coupling agent.

[0056] In other various embodiments, dilatant compounds are described herein. The dilatant compounds include a silicone fluid and a nanomaterial dispersed in the silicone fluid. The nanomaterial is functionalized with at least one silane coupling agent. In some embodiments, the nanomaterial is HALLOYSITE nanotubes. In some embodiments, the nanomaterial is cross- linked to the silicone fluid through the at least one silane coupling agent.

Experimental Examples

[0057] The following examples are provided to more fully illustrate some of the embodiments disclosed hereinabove. It should be appreciated by those of ordinary skill in the art that the techniques disclosed in the examples that follow represents techniques that constitute illustrative modes for practice of the disclosure. Those of ordinary skill in the art should, in light of the present disclosure, appreciate that many changes can be made in the specific embodiments that are disclosed and still obtain a like or similar result without departing from the spirit and scope of the disclosure.

[0058] Example 1: Ballistic Testing of an Illustrative Laminate Material. FIGURE 5 shows an illustrative schematic of a laminate material produced according to one embodiment of the present disclosure. Strike face 1 is composed of two layers of metal underlayer 51 and 54, each individually in contact with thermoset layers 52 and 55. Strike face 1 is further coated on its exterior with a thermoplastic

6. The laminate material of claim 3, wherein the polymer fibers comprise ultra-high molecular weight polyethylene.

7. The laminate material of claim 3, wherein the dilatant compound coats the polymer fibers.

8. The laminate material of claim 1, wherein the dilatant compound comprises a silicone fluid cross-linked with at least one silane coupling agent.

9. The laminate material of claim 8, wherein the first layer further comprises a nanomaterial.

10. The laminate material of claim 9, wherein the nanomaterial comprises HALLOYSITE nanotubes.

11. The laminate material of claim 10, wherein the HALLOYSITE nanotubes are bonded to the at least one silane coupling agent.

12. The laminate material of claim 1, wherein the first layer further comprises a nanomaterial.

13. The laminate material of claim 12, wherein the nanomaterial comprises HALLOYSITE nanotubes.

14. The laminate material of claim 13, wherein the HALLOYSITE nanotubes are further modified with at least one silane coupling agent.

15. The laminate material of claim 1, wherein the ceramic material is selected from the group consisting of boron carbide, silicon carbide, cubic boron nitride and combinations thereof.

16. The laminate material of claim 15, wherein the ceramic material is silane functionalized with at least one silane coupling agent.

17. The laminate material of claim 1 , wherein the strike face material comprises a composite comprising at least one metal underlayer and a polymer material.

18. The laminate material of claim 17, further comprising: a nanomaterial dispersed in the polymer material.

19. The laminate material of claim 18, wherein the at least one metal underlayer, the polymer material, and the nanomaterial are silane functionalized with at least one silane coupling agent.

20. The laminate material of claim 18, wherein the nanomaterial is selected from the group consisting of carbon nanotubes, HALLO YSITE nanotubes, and combinations thereof.

21. The laminate material of claim 17, wherein the at least one metal underlayer comprises a $TiAl_6V_4$ alloy.

22. The laminate material of claim 17, wherein the at least one metal underlayer is patterned with a plurality of holes.

23. The laminate material of claim 22, further comprising: a nanomaterial dispersed in the polymer material; and wherein the polymer material fills at least a portion of the plurality of holes.

24. A laminate material comprising: a first layer comprising a dilatant compound and a polymer fiber component; wherein polymer fiber component is arranged in sub-layers within the first layer; a second layer comprising a ceramic material; and a third layer comprising a strike face material; wherein the strike face material comprises: at least one metal underlayer; wherein the at least one metal underlayer is patterned with a plurality of holes; a polymer material; and a nanomaterial dispersed in the polymer material; wherein the polymer material fills at least a portion of the plurality of holes; wherein the second layer is interposed between the first layer and the third layer.

US7888419B2 * 2005-09-02 2011-02-15 Naturalnano, Inc. Polymeric composite including nanoparticle filler

US20080249221A1 * 2007-04-06 2008-10-09 Naturalnano Research, Inc. Polymeric adhesive including nanoparticle filler

US7966923B2 * 2007-06-28 2011-06-28 The United States Of America As Represented By The Secretary Of The Army Conformable self-healing ballistic armor

* Cited by examiner, † Cited by third party

Cited By (9)

Publication number Priority date Publication date Assignee Title

WO2015012917A3 * 2013-04-26 2015-03-19 E. I. Du Pont De Nemours And Company Ballistic resistant armor article

US9023451B2 2011-09-06 2015-05-05 Honeywell International Inc. Rigid structure UHMWPE UD and composite and the process of making

US9023450B2 2011-09-06 2015-05-05 Honeywell International Inc. High lap shear strength, low back face signature UD composite and the process of making

US9023452B2 2011-09-06 2015-05-05 Honeywell International Inc. Rigid structural and low back face signature ballistic UD/articles and method of making

US9163335B2 2011-09-06 2015-10-20 Honeywell International Inc. High performance ballistic composites and method of making

US9168719B2 2011-09-06 2015-10-27 Honeywell International Inc. Surface treated yarn and fabric with enhanced physical and adhesion properties and the process of making

US9222864B2 2011-09-06 2015-12-29 Honeywell International Inc. Apparatus and method to measure back face signature of armor

WO2015130376A3 * 2013-12-16 2016-01-28 E. I. Du Pont De Nemours And Company A rigid ballistic composite article comprising a resi binder layer comprising a nano size filler

Family To Family Citations

US8225704B2 2010-01-16 2012-07-24 Nanoridge Materials, Inc. Armor with transformed nanotube material

* Cited by examiner, † Cited by third party, ‡ Family to family citation

Similar Documents

Publication Publication Date Title

Lee et al. 2003 The ballistic impact characteristics of Kevlar® woven fabrics impregnated with a colloidal shear thickening fluid

Peijs et al. 1990 Hybrid composites based on polyethylene and carbon fibres Part 3: Impact resistant structural composites through damage management

US6826996B2 2004-12-07 Structural composite armor and method of manufacturing it

Date Code Title Description

2010-12-22 121 Ep: the epo has been informed by wipo that ep was designated in this application

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Kind code of ref document: A2

2011-07-13 NENP Non-entry into the national phase in:

Ref country code: DE

2012-02-15 122 Ep: pct application non-entry in european phase

Ref document number: 10767452

Country of ref document: EP

Kind code of ref document: A2