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(54) BALLISTIC RESISTANT PANEL

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Publication Classification

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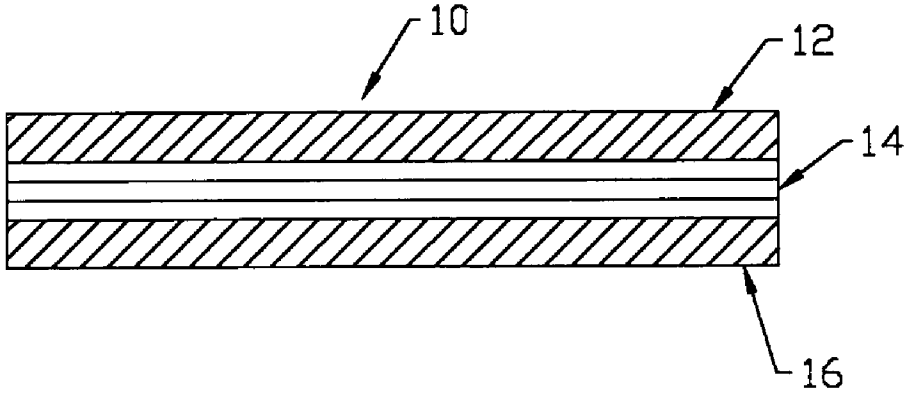
(52) **U.S. Cl.** **2/2.5**

(57) **ABSTRACT**

A ballistic resistant panel for use in protective garments. The ballistic resistant panel comprises at least two layers of multiple plies of a woven fibrous material wherein the plies of each layer are loosely stitched together within the respective layer and the layers are fastened together at the periphery of the panel. The loose construction yields a panel that is light-weight and more economic to manufacture.



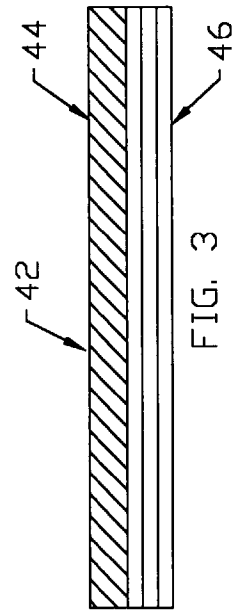


FIG. 3

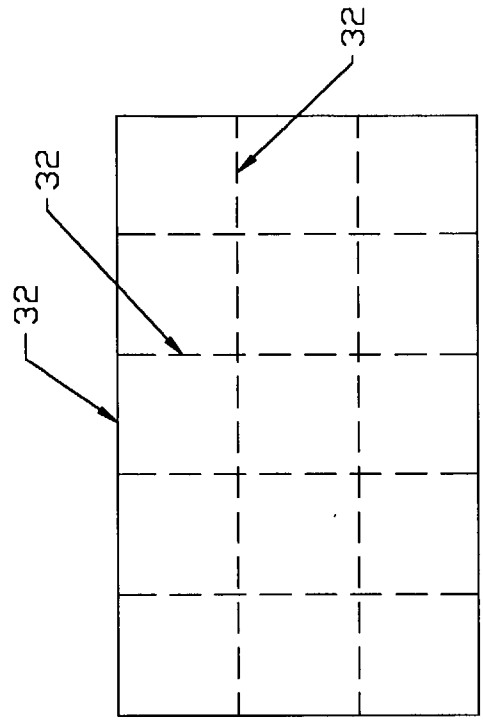


FIG. 4

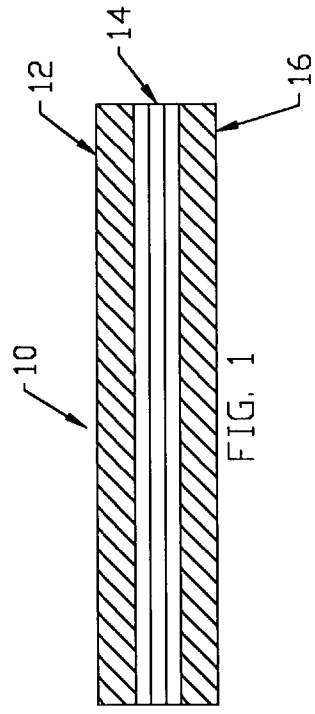


FIG. 1

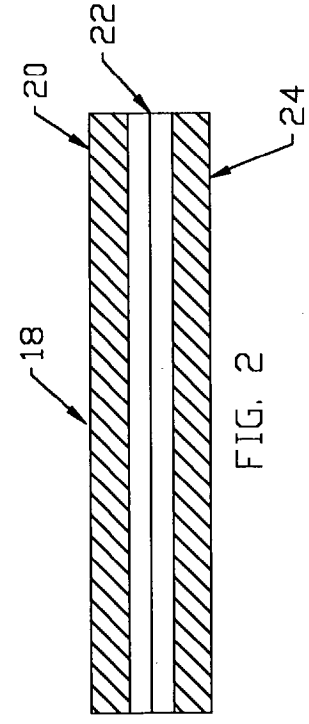


FIG. 2

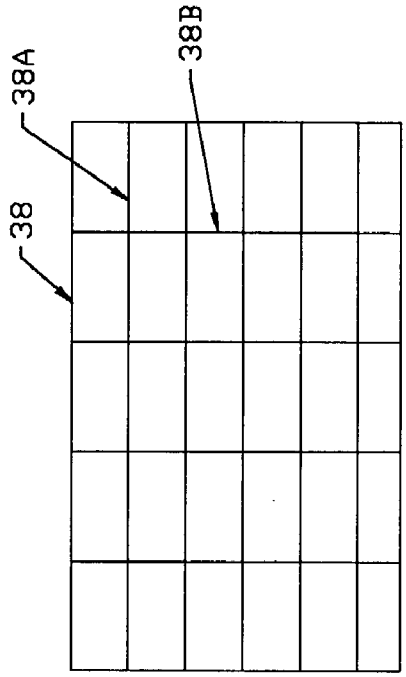


FIG. 7

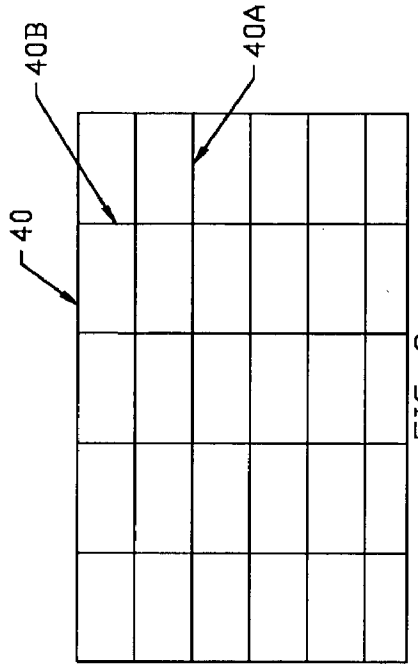


FIG. 8

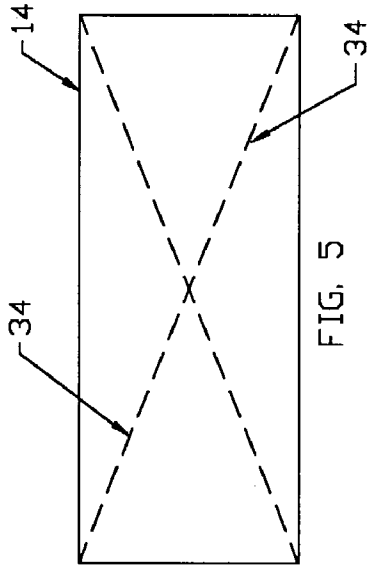


FIG. 5

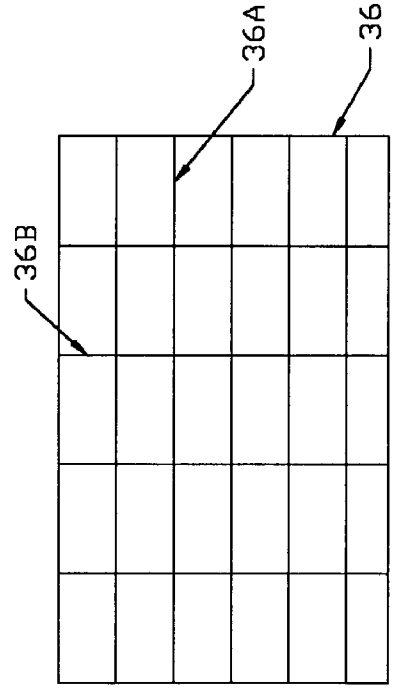


FIG. 6

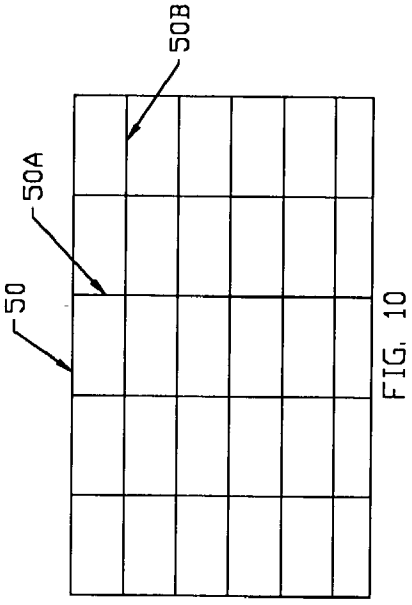


FIG. 10

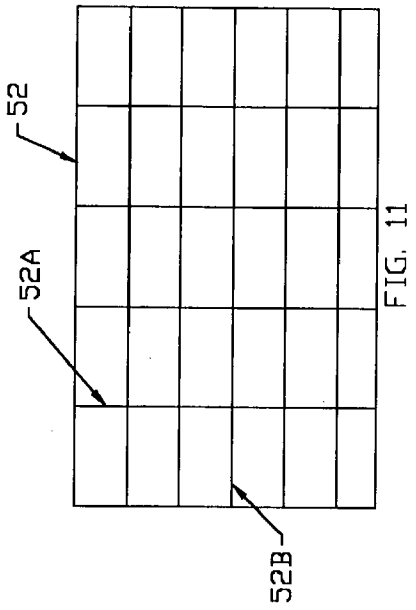


FIG. 11

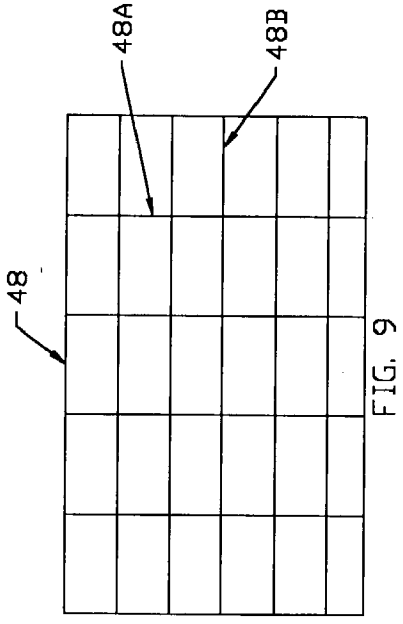


FIG. 9

BALLISTIC RESISTANT PANEL

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Application No. 60/408,631 filed Jan. 5, 2002.

FIELD OF THE INVENTION

[0002] The present invention relates to protective body armor that meets NIJ Standard-0101.04 for Type IIIA, II and IIA ballistic threats. More particularly, this invention relates to ballistic resistant panels used in such protective garments.

BACKGROUND OF THE INVENTION

[0003] Protective garments like personal body armor are constructed with inserts of ballistic resistant panels, which protect the wearer from the impact forces of a fired projectile. Personal body armors are classified into several types by the level of protection they provide. The National Institute of Justice (NIJ) has defined minimum performance requirements for the ballistic resistance of personal body armor according to the type of ballistic threat. According to NIJ Standard-0101.04, which is herein incorporated by reference, ballistic resistant body armor suitable for full-time wear throughout an entire duty shift are classified as Types I, IIA, II, and IIIA. Of these, Type IIIA protects against the greatest ballistic threat followed by Type II, Type IIA, and Type I in decreasing order of ballistic protection. Body armor which provides protection against a greater ballistic threat would also meet the requirements for protection against the lesser ballistic threats under the NIJ classifications. For example, body armor which protects against a Type III ballistic threat also protects against Types II, IIA, and I threat levels. In addition to the level of ballistic protection, it is important that the body armor be comfortable to wear so that that the persons it is intended to protect are more inclined to wear it and may wear it without difficulty over extended periods of time.

[0004] Conventional ballistic resistant panels are constructed of multiple woven plies of high-tensile-strength fibers such as aramid fibers. Examples of ballistic resistant fibers which are commercially available include Kevlar® which is manufactured by E. I. DuPont de Nemours & Company of Wilmington, Del. and Twaron® T-2000 which is manufactured by AKZO NOBEL, Inc. Typically, the woven plies in the ballistic resistant panels are held together with tight stitches sewn through multiple plies. This results in compacted layers which form a more or less solid ballistic panel. In order to protect the wearer of the garment, substantial numbers of compacted layers are used which tends to make the protective garment bulky, heavy and uneconomical. It would be advantageous to have ballistic resistant panels which provide the same protection level as prior art panels but with a lesser number of plies.

SUMMARY OF THE INVENTION

[0005] It is an object of the invention to obviate the disadvantages of the prior art.

[0006] It is another object of the invention to provide a ballistic resistant panel for use in protective garments which is light-weight and economical to manufacture.

[0007] It is a further object of the invention to provide a ballistic resistant panel which meets NIJ Standard-0101.04 for Type IIIA, Type II and Type IIA ballistic threats.

[0008] In accordance with an object of the invention, there is provided a ballistic resistant panel comprising at least two layers, the layers having multiple plies of a woven fibrous material, the multiple plies of each layer being loosely stitched together within the respective layer, the layers being fastened together at the periphery of the panel.

[0009] In accordance with another object of the invention, the ballistic resistant panel has three layers, the plies of the first and third layers being loosely stitched together in a square pattern, the second layer being disposed between the first and third layers, and the plies of the second layer being loosely stitched together in a crossed-diagonal pattern.

[0010] In accordance with another object of the invention, the ballistic resistant panel has two layers, the plies of the first layer being loosely stitched together in a square pattern, and the plies of the second layer being loosely stitched together in a crossed-diagonal pattern.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] **FIG. 1** is a cross-sectional view of an embodiment of the ballistic resistant panel of this invention which meets NIJ Standard-0101.04 for a Type IIIA ballistic threat.

[0012] **FIG. 2** is a cross-sectional view of an embodiment of the ballistic resistant panel of this invention which meets NIJ Standard-0101.04 for a Type II ballistic threat.

[0013] **FIG. 3** is a cross-sectional view of an embodiment of the ballistic resistant panel of this invention which meets NIJ Standard-0101.04 for a Type IIA ballistic threat.

[0014] **FIG. 4** is a view illustrating a square stitching pattern of the present invention.

[0015] **FIG. 5** is a view illustrating a crossed-diagonal stitching pattern of the present invention.

[0016] **FIG. 6** illustrates the weave of the first and third layers of woven lyotropic liquid crystal polymer fibers of a first embodiment.

[0017] **FIG. 7** illustrates the weave of the first and third layers of woven lyotropic liquid crystal polymer fibers of a second embodiment.

[0018] **FIG. 8** illustrates the weave of the first layer of woven lyotropic liquid crystal polymer fibers of a third embodiment.

[0019] **FIG. 9** illustrates the weave of the second layer of woven lyotropic liquid crystal polymer fibers of a first embodiment.

[0020] **FIG. 10** illustrates the weave of the second layer of woven lyotropic liquid crystal polymer fibers of a second embodiment.

[0021] **FIG. 11** illustrates the weave of the second layer of woven lyotropic liquid crystal polymer fibers of a third embodiment.

DETAILED DESCRIPTION OF THE INVENTION

[0022] The ballistic resistant panel of this invention is constructed of at least two layers of multiple plies of

high-tensile-strength fibrous materials. Preferably, the fibrous material is comprised of lyotropic liquid crystal polymer fibers. An example of which is ZYLON® manufactured by Toyobo Co., Ltd. of Osaka, Japan. ZYLON® is a high-tensile-strength fiber which consists of rigid-rod chain molecules of poly(p-phenylene-2,6-benzobisoxazole)(PBO). The lyotropic liquid crystal polymer fibrous material within the embodiments described herein is preferably constructed of fibers that have a denier of 500 and a thickness of 0.037 in.

[0023] As described above, prior art panels typically are held together with tight stitches sewn through multiples plies of ballistic resistant material. The tight stitching tends to compact the layers of the panel, yielding a more or less a solid panel. Unlike the prior art, loose stitching is used to join the multiple plies within the layers of the panel of this invention. This allows for some movement within each layer of the panel. The layers are then fastened together at the periphery of the panel which further provides for a generally loose panel construction. Since the layers are held together only at the periphery of the panel, the layers are allowed to have independent movement as they come into contact with the projectile.

[0024] The discovery that loosely connected plies of material react much better in absorbing ballistic impact forces was unexpected and contrary to conventional thinking. While not wishing to be bound by theory, it is believed that loosely stitched layers react similar to someone hitting a ball into a pillow. Each layer is independently deformed in the direction of the impact force and progressively diminishes the energy of the projectile. Since the ballistic resistant panels of present invention absorb the energy of a fired projectile much better than the tightly stitched prior art panels, fewer plies of ballistic resistant material can be used to achieve the same level of protection. This makes the panels much lighter in weight and less expensive to manufacture.

[0025] **FIG. 1** is a cross-sectional view of a first embodiment of the ballistic resistant panel of this invention which meets NIJ Standard-0101.04 for a Type IIIA ballistic threat. The panel **10** is constructed of three layers. The first layer **12**, the second layer **14** and the third layer **16** each contain of four plies of a woven lyotropic liquid crystal polymer fibrous material. The four plies of the first **12** and the third **16** layers are loosely stitched together in a square pattern within the respective layer. The four plies of the second layer **14** are loosely stitched together in a crossed-diagonal pattern.

[0026] Referring to **FIG. 4**, the square stitching pattern of the first and third layers **12**, **16** is shown with stitches **32** running in lines perpendicular and parallel to each other. The stitches **32** are positioned to reduce the amount of backface when placed against the body of a wearer. Backface is defined as the amount of blunt trauma the body of a wearer would feel when a fired projectile hits the panel. The stitches **32** are preferably a one-inch diamond stitch, 3½ stitches per inch, and sewn through the four plies of each of the first **12** and third **16** layers of panel **10**. Preferably, the stitches **32** are comprised of aramid threads. In **FIG. 5** there is shown the crossed-diagonal stitching pattern of the second layer **14**. The stitches **34** run in diagonal lines from corner to corner, crossing in the center of the layer. The stitches **34** are preferably a one-inch diamond stitch, 3½ stitches per inch, and sewn through the four plies of the second layer **14**. Again, the stitching is preferably comprised of aramid threads. The three layers of panel **10** are fastened at the periphery of the panel to hold the layers together while still preserving independent movement. Preferably, the layers are stitched together at the corners of the panel.

[0027] As shown in **FIG. 6**, the weave **36** for the first **12** and third **16** layers of woven lyotropic liquid crystal polymer fibrous material has a warp to fill ratio of 11 by 28 fibers per inch. There are twenty-eight horizontal warp fibers **36**A and eleven vertical fill fibers **36**B per inch for each ply of woven lyotropic liquid crystal polymer fibrous material. Referring **FIG. 9**, the weave **48** for the second layer **14** of woven lyotropic liquid crystal polymer fibrous material has a warp to fill ratio of **30** by **30** fibers per inch. There are thirty horizontal warp fibers **48**A and thirty vertical fill fibers **48** per inch for each ply of woven lyotropic liquid crystal polymer fibrous material.

[0028] Preferably, panel **10** has a thickness of about 0.15 inches and an areal density of not more than about 0.84 pounds per square foot (PSF) while providing protection from a Type IIIA ballistic threat. A test panel was constructed according to this first embodiment and tested for compliance with NIJ Standard-0101.04 for a Type IIIA ballistic threat. According to the NIJ Standard, a Type IIIA body armor will protect against 9 mm Full Metal Jacketed Round Nose (FMJ RN) bullets with nominal masses of 8.0 g (124 gr) impacting at a minimum velocity of 427 m/s (1400 ft/s) or less, and 44 Magnum Jacketed Hollow Point (JHP) bullets, with nominal masses of 15.6 g (240 gr) impacting at a minimum velocity of 427 m/s (1400 ft/s) or less. It also provides protection against threat level Types I, IIA and II as defined in the NIJ Standard. The test data for the panel are presented in Table 1 below.

TABLE 1

TYPE IIIA Ballistic Panel

Sample	Sample Weight	Wet Dry	0–30 deg. Angle	Caliber	Bullet Wt. (gr) & type	Velocity (Fps)	Penetration BFS (mm)
1-1	4.25	Wet	0	44 Mag	240 SJHP	1431	36
1-2	4.25	Wet	30	44 Mag	240 SJHP	1429	38
1-3	4.25	Wet	0	44 Mag	240 SJHP	1438	36
1-4	4.25	Wet	30	44 Mag	240 SJHP	1432	37
1-5	4.25	Wet	0	44 Mag	240 SJHP	1445	37
1-6	4.25	Wet	30	44 Mag	240 SJHP	1420	39
1-7	4.25	Wet	0	44 Mag	240 SJHP	1445	29
1-8	4.25	Wet	30	44 Mag	240 SJHP	1428	29

[0029] A second embodiment of the present invention for NIJ Standard-0101.04 Type II ballistic threats is shown in cross-section in **FIG. 2**. The first layer **20** and the third layer **24** of panel **18** are constructed of multiple plies of woven lyotropic liquid crystal polymer fibrous material with the second layer **22** constructed of at least one ply of woven lyotropic liquid crystal polymer fibrous material. Preferably, the first layer **20** and the third layer **24** each have three plies of woven lyotropic liquid crystal polymer fibrous material. The second layer **22** preferably consists of four plies of woven lyotropic liquid crystal polymer fibrous material. The three plies of the first **20** and third **24** layers of panel **18** are loosely stitched together within their respective layers using

the square pattern shown in **FIG. 4**. The four plies of the second layer **22** are loosely stitched together in the crossed-diagonal pattern shown in **FIG. 5**. The loose stitching is preferably a one-inch diamond stitch at 3½ stitches per inch and comprised of aramid threads. The three layers are held together with stitches sewn through the layers at the corners of panel **18**.

[**0030**] As shown in **FIG. 7**, the weave **38** for the first and third layers of woven lyotropic liquid crystal polymer fibrous material has a warp to fill ratio of 11 by 28 fibers per inch. There are twenty-eight horizontal warp fibers **38**A and eleven vertical fill fibers **38**B per inch for each ply of woven lyotropic liquid crystal polymer fibrous material. As shown in **FIG. 10**, the weave **50** for the second layer of woven lyotropic liquid crystal polymer fibrous material has a warp to fill ratio of 30 by 30 fibers per inch. There are thirty horizontal warp fibers **50**A and thirty vertical fill fibers **50**B per inch for each ply of woven lyotropic liquid crystal polymer fibrous material.

[**0031**] Preferably, panel **18** has a thickness of about 0.13 inches and an areal density of not more than about 0.66 PSF while providing effective protection for a Type II ballistic threat. According to NIJ Standard-0101.04, Type II body armor protects against 9 mm Full Metal Jacketed Round Nose (FMJ RN) bullets with nominal masses of 8.0 g (124 gr) impacting at a minimum velocity of 358 m/s (1175 ft/s) or less, and 357 Magnum Jacketed Soft Point (JSP) bullets, with nominal masses of 10.2 g (158 gr) impacting at a minimum velocity of 427 m/s (1400 ft/s) or less. It also provides protection against Type I and IIA ballistic threats. Test data for a panel constructed according to the second embodiment are shown in Table 2 below.

TABLE 2

TYPE II Ballistic Panel

Sample	Sample Weight	Wet Dry	0–30 deg. Angle	Caliber	Bullet Wt. (gr) & type	Velocity (Fps)	Penetration BFS (mm)
2-1	3.67	Wet	0	357 Mag	158 JSP	1439	28
2-2	3.67	Wet	30	357 Mag	158 JSP	1439	28
2-3	3.67	Wet	0	357 Mag	158 JSP	1459	29
2-4	3.67	Wet	30	357 Mag	158 JSP	1451	30
2-5	3.67	Wet	0	357 Mag	158 JSP	1438	42
2-6	3.67	Wet	30	357 Mag	158 JSP	1438	29
2-7	3.67	Wet	0	357 Mag	158 JSP	1464	27
2-8	3.67	Wet	30	357 Mag	158 JSP	1462	30

[**0032**] A third embodiment of the present invention for NIJ Standard-0101.04 Type IIA ballistic threats is shown in cross-section in **FIG. 3**. The first layer **44** of panel **42** is constructed of multiple plies of woven lyotropic liquid crystal polymer fibrous material with the second layer **46** constructed of at least one ply of woven lyotropic liquid crystal polymer fibrous material. Preferably, the first **44** and second **46** layers are comprised of four plies each of woven lyotropic liquid crystal polymer fibrous material. The plies of the first layer **44** are loosely stitched together in a square pattern as shown in **FIG. 4**. The plies of the second layer **46** are loosely stitched together in a crossed-diagonal pattern as shown in **FIG. 5**. The stitches are preferably a one-inch diamond stitch at 3½ stitches per inch and comprised of aramid threads.

[**0033**] As shown in **FIG. 8**, the weave **40** for the first layer **44** of woven lyotropic liquid crystal polymer fibrous material has a warp to fill ratio of 11 by 28 fibers per inch. There are twenty-eight horizontal warp fibers **40**A and eleven vertical fill fibers **40**B per inch. As shown in **FIG. 11**, the weave **52** for the second layer **46** of woven lyotropic liquid crystal polymer fibrous material has a warp to fill ratio of 30 by 30 fibers per inch. There are thirty horizontal warp fibers **52**A and thirty vertical fill fibers **52**B per inch.

[**0034**] Preferably, panel **42** has a thickness of about 0.10 inches and an areal density of not more than about 0.51 PSF while providing effective protection against Type IIA ballistic threats. According to NIJ Standard-0101.04, Type ITA body armor will protect against 9 mm Full Metal Jacketed Round Nose (FMJ RN) bullets with nominal masses of 8.0 g (124 gr) impacting at a minimum velocity of 332 m/s (1090 ft/s) or less, and 40 S&W caliber Full Metal Jacketed (FMJ) bullets, with nominal masses of 11.7 g (180 gr) impacting at a minimum velocity of 312 m/s (1025 ft/s) or less. It also provides protection Type I ballistic threats. Test data for a panel constructed in accordance with the third embodiment is presented in Table 3 below.

TABLE 3

TYPE IIA Ballistic Panel

Sample	Sample Weight	Wet Dry	0–30 deg. Angle	Caliber	Bullet Wt. (gr) & type	Velocity (Fps)	Penetration BFS (mm)
3-1	3.00	Wet	0	40 S&W	180 FMJ	1054	27
3-2	3.00	Wet	30	40 S&W	180 FMJ	1050	26
3-3	3.00	Wet	0	40 S&W	180 FMJ	1051	27
3-4	3.00	Wet	30	40 S&W	180 FMJ	1057	25
3-5	3.00	Wet	0	40 S&W	180 FMJ	1048	27
3-6	3.00	Wet	30	40 S&W	180 FMJ	1047	27
3-7	3.00	Wet	0	40 S&W	180 FMJ	1052	25
3-8	3.00	Wet	30	40 S&W	180 FMJ	1046	28

[**0035**] While there have been provided several embodiments of the invention, there are many other variations of the invention which may be made without departing from the scope of the invention as set forth in the appended claims.

What is claimed is:

1. A ballistic resistant panel comprising at least two layers, the layers having multiple plies of a woven fibrous material, the multiple plies of each layer being loosely stitched together within the respective layer, the layers being fastened together at the periphery of the panel.

2. The ballistic resistant panel of claim 1 wherein the panel has three layers, the plies of the first and third layers being loosely stitched together in a square pattern, the second layer being disposed between the first and third layers, and the plies of the second layer being loosely stitched together in a crossed-diagonal pattern.

3. The ballistic resistant panel of claim 2 wherein each layer has four plies of woven lyotropic liquid crystal polymer fibers.

4. The ballistic resistant panel of claim 2 wherein the first and third layers are comprised of three plies of woven lyotropic liquid crystal polymer fibers and the second layer is comprised of four plies of woven lyotropic liquid crystal polymer fibers.

5. The ballistic resistant panel of claim 1 wherein the panel has two layers, the plies of the first layer being loosely stitched together in a square pattern, and the plies of the second layer being loosely stitched together in a crossed-diagonal pattern.

6. The ballistic resistant panel of claim 5 wherein each layer is comprised of four plies of woven lyotropic liquid crystal polymer fibers.

7. The ballistic resistant panel of, claim 3 wherein the loose stitching is a one-inch diamond stitch at 3½ stitches per inch.

8. The ballistic resistant panel of claim 3 wherein the plies of the first and third layers have a warp to fill ratio of 11 by 28 fibers per inch and the plies of the second layer have a warp to fill ratio of 30 by 30 fibers per inch.

9. The ballistic resistant panel of claim 3 wherein the panel has an areal density of not more than about 0.84 pounds per square foot.

10. The ballistic resistant panel of claim 9 wherein the panel has a thickness of about 0.15 inches.

11. The ballistic resistant panel of claim 4 wherein the loose stitching is a one-inch diamond stitch at 3½ stitches per inch.

12. The ballistic resistant panel of claim 4 wherein the plies of the first and third layers have a warp to fill ratio of 11 by 28 fibers per inch and the plies of the second layer have a warp to fill ratio of 30 by 30 fibers per inch.

13. The ballistic resistant panel of claim 4 wherein the panel has an areal density of not more than about 0.66 pounds per square foot.

14. The ballistic resistant panel of claim 13 wherein the panel has a thickness of about 0.13 inches.

15. The ballistic resistant panel of claim 6 wherein the loose stitching is a one-inch diamond stitch at 3½ stitches per inch.

16. The ballistic resistant panel of claim 6 wherein the plies of the first layer have a warp to fill ratio of 11 by 28 fibers per inch and the plies of the second layer have a warp to fill ratio of 30 by 30 fibers per inch.

17. The ballistic resistant panel of claim 6 wherein the panel has an areal density of not more than about 0.51 pounds per square foot.

18. The ballistic resistant panel of claim 17 wherein the panel has a thickness of about 0.10 inches.

19. The ballistic resistant panel of claim 1 wherein the panel has an areal density of not more than about 0.84 pounds per square foot and meets NIJ Standard-0101.04 for Type IIIA ballistic threats.

20. The ballistic resistant panel of claim 1 wherein the panel has an areal density of not more than about 0.66 pounds per square foot and meets NIJ Standard-0101.04 for Type II ballistic threats.

21. The ballistic resistant panel of claim 1 wherein the panel has an areal density of not more than about 0.51 pounds per square foot and meets NIJ Standard-0101.04 for Type IIA ballistic threats.

22. The ballistic resistant panel of claim 19 wherein the panel has a thickness of about 0.15 inches.

23. The ballistic resistant panel of claim 20 wherein the panel has a thickness of about 0.13 inches.

24. The ballistic resistant panel of claim 21 wherein the panel has a thickness of about 0.10 inches.

* * * * *