



(51) International Patent Classification: Not classified

(21) International Application Number:

PCT/US2009/006225

(22) International Filing Date:

20 November 2009 (20.11.2009)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

12/313,946 26 November 2008 (26.11.2008) US

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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(54) Title: LAMINATED BALLISTIC SHEET

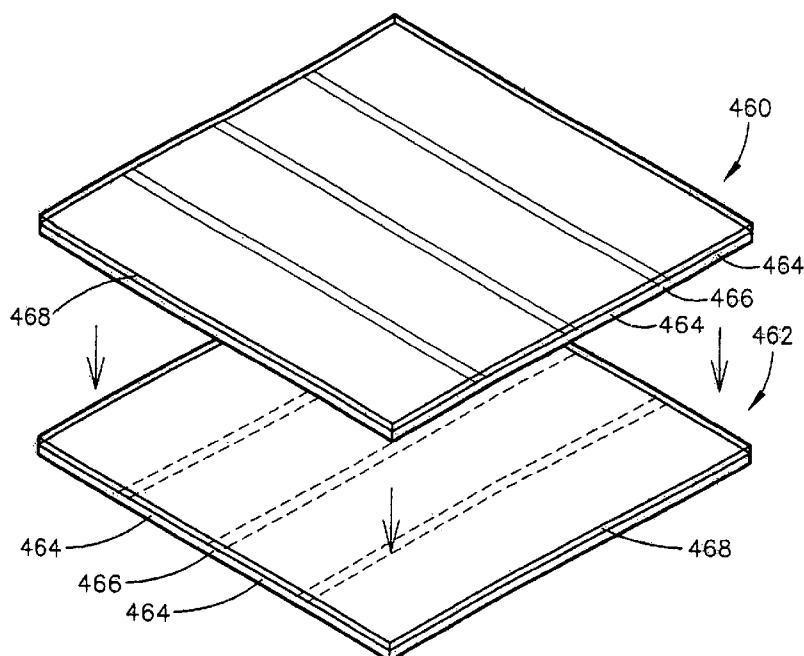


FIG. 10

(57) Abstract: A non-woven ballistic material that demonstrates exceptional ballistic properties which ballistic material is fabricated by the lamination or angular lamination of a plurality of wide sheets of UHMWPE comprising a plurality of strips of highly oriented

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Published:

- *without international search report and to be republished
upon receipt of that report (Rule 48.2(g))*

ultra high molecular weight polyethylene partially overlapped or abutted longitudinally to define joints between adjoining strips wherein the thickness of the joint is less than about 80% of the thickness of the sum of the thicknesses of the adjoining strips that make up the joint.

Laminated Ballistic Sheet

Field of the Invention

01) The present invention relates to laminated ballistic sheet and more particularly to such materials that are fabricated by the lamination of sheets formed of strips or tapes of ultra high molecular weight polyethylene (UHMWPE) that have been joined to form sheets and subsequently laminated.

Background of the Invention

02) U.S. Patent Application Serial No. 11/787,094 (published October 16, 2008 as US 2008-0254260 A1) describes a wide sheet of highly oriented ultra high molecular weight polyethylene comprising a plurality of strips of highly oriented ultra high molecular weight polyethylene partially overlapped or abutted longitudinally to define joints between adjoining strips wherein the thickness of the joint is less than about 80% of the thickness of the sum of the thicknesses of the adjoining strips that make up the joint. A continuous method for the production of such materials comprising subjecting longitudinally overlapping or abutted strips of these materials to temperatures below the melting point of the UHMWPE and pressures over 300 pli is also disclosed in this application.

03) U.S. Patent Application Serial No. 11/787,260 (published October 16, 2008 as US 2008-0251212) describes apparatus for the continuous fabrication of wide polymer sheet

from a plurality of polymer strips of indeterminate length abutting or partially overlapped longitudinally to define joints between adjoining strips.

04) U.S. Patent Application Serial No. 11/881,863 (filed as PCT/US 08433 on 3 April 2008) describes a ballistic-resistant panel in which the entire panel or a strike-face portion thereof is formed of a plurality of sheets of high modulus high molecular weight polyethylene tape. The sheets of high modulus polyethylene tape can be in the form of cross-plyed laminated layers of tape strips or a woven fabric of tape strips. The strips of UHMWPE tape include a width of at least one inch and a modulus of greater than 1400 grams per denier. The ballistic-resistant panel may include a backing layer of conventional high modulus fibers embedded in resin. A wide variety of adhesives were found acceptable for bonding the cross-plyed layers of high modulus polyethylene tape together for forming the ballistic-resistant panels according to this disclosure.

05) While each of these pending applications describes highly useful materials and methods and apparatus for their fabrication, none describes a ballistic laminate fabricated from a wide sheet of highly oriented ultra high molecular weight polyethylene comprising a plurality of strips of highly oriented ultra high molecular weight polyethylene partially overlapped or abutted longitudinally to define joints between adjoining strips wherein the thickness of the joint is less than about 80% of the thickness of the sum of the thicknesses of the adjoining strips that make up the joint.

06) Accordingly, there remains an opportunity to provide a ballistic laminate fabricated from the wide sheet product described in U.S Patent Application Serial No.11/787,094.

Object of the Invention

07) It is therefore an object of the present invention to provide am UHMWPE ballistic laminate that exhibits exceptional ballistic properties.

Summary of the Invention

08) According to the present invention there is provided a non-woven ballistic material that demonstrates exceptional ballistic properties which ballistic material is fabricated by the lamination or angular lamination of a plurality of wide sheets of UHMWPE comprising a plurality of strips of highly oriented ultra high molecular weight polyethylene partially overlapped or abutted longitudinally to define joints between adjoining strips wherein the thickness of the joint is less than about 80% of the thickness of the sum of the thicknesses of the adjoining strips that make up the joint.

Description of the Drawings

- 09) **Figure 1 is a schematic side view of the apparatus useful in the fabrication of the wide sheet ballistic materials useful in the successful practice of the present invention.**
- 10) **Figure 2 is a schematic top view of the apparatus useful in the fabrication of the wide sheet ballistic materials useful in the successful practice of the present invention.**
- 11) **Figure 3 is a schematic side view of the calendar roll stand portion of the apparatus useful in the fabrication of the wide sheet ballistic materials useful in the successful practice of the present invention.**
- 12) **Figure 4 is a schematic partial top view of a portion of the initial and final alignment guide zones of the apparatus useful in the fabrication of the wide sheet ballistic materials useful in the successful practice of the present invention.**
- 13) **Figure 5 is a cross-sectional view of the overlap area between two adjoining narrow strips of highly oriented UHMWPE prior to bonding in accordance with the practice described in U.S. Patent Application Serial No. 11/787,094**
- 14) **Figure 6 is a cross-sectional representation of the joint volume between two highly oriented UHMWPE tapes after treatment in accordance with the method described in U.S. Patent Application Serial No. 11/787,094**
- 15) **Figure 7 is a partially phantom top plan view of the UHMWPE wide sheet of U.S. Patent Application Serial No. 11/787,094**

prior to processing in accordance with the method described in that application.

16) Figures 8 and 9 are cross-sectional views depicting an alternative preferred embodiment of the wide sheet described in U.S. Patent Application Serial No. 11/787,094 and useful in the successful practice of the present invention.

17) Figure 10 is a schematic representation in perspective view of two sheets or layers of adhesive-coated unidirectional non-fibrous UHMWPE tape prior to being fused together with heat and pressure to form a cross-ply laminate for use in the construction of a ballistic laminate according to the present invention.

18) Figure 11 is a schematic representation as viewed from the side of two sheets of unidirectional non-fibrous UHMWPE tape prior to being fused together with heat and pressure to form a cross-ply laminate.

Detailed Description

19) As used herein, the terms “substantially flat”, “essentially flat” and “substantially pure” are meant and intended to have the following meanings: “substantially flat” refers to sheet material in accordance with the present invention wherein a joint between two adjoining strips of material has a thickness that is not greater than 80% of the combined thicknesses of the adjoining/overlapping/abutting strips; “essentially flat” refers to sheet material in accordance with the present invention wherein a joint between two adjoining

strips is essentially the same thickness as that of the strips being joined with little if any thickness difference therebetween; and “substantially pure” refers to UHMWPE that contains no foreign materials or substances that negatively affect the properties of the UHMWPE except as artifacts of the UHMWPE production process such as catalysts, etc.

20) The starting material UHMWPE wide sheets of the present invention are those fabricated as described in aforementioned U.S. Patent Application Serial No. 11/787,094 (hereinafter the ‘094 application) which is incorporated herein by reference in its entirety from strips of UHMWPE prepared in accordance with the methods described in the following U.S. Patents: 6,951,685; 4,879,076; 5,091,133; 5,106,555; 5,106,558; and 5,578,373 the teachings of which are all incorporated herein by reference in their entireties. Particularly preferred as the starting materials are the UHMWPE materials prepared as described in the aforementioned U.S. Patent No. 6,951,685. Such materials comprise highly oriented UHMWPE of high purity.

21) According to the process described in the aforementioned ‘094 application, wide UHMWPE sheet is produced by a process that comprises calendering an array of overlapping or abutting strips of indeterminate length prepared as described in the recited prior art at a temperature below the melting point of the UHMWPE, generally in a range of between about 120°C and about 155°C (depending upon the tension applied to the strips during bonding as described below) at a pressure above about 300 pounds per lineal inch (pli) and under a tension of between about 0.3 grams/denier and about 5 grams/denier. The calendering apparatus and detailed description of the method for the production of

these wide sheets are depicted and described in U.S. Patent Application Serial No. 11/787,260 (the '260 application hereinafter) which is incorporated herein by reference in its entirety.

22) Referring now to accompanying Figures 5-7, a first embodiment of the wide UHMWPE sheet of the present invention 300 comprises a series of parallel and overlapped tapes or strips 302 of indeterminate length. As used herein, in relation to this first preferred embodiment, the term "joint" is meant to define and refer to the overlapped areas/volumes 304 depicted in Figure 6. As depicted in Figures 5, 6, 10 and 11, the molecules in two abutting or overlapping strips or tapes 302A and 302B are schematically depicted as triangles and circles to permit differentiation in the discussion that follows.

23) As depicted in Figure 5, 6 and 7, a first preferred embodiment of the wide sheet 300 of the wide sheet useful in the successful practice of the present invention is produced by overlaying an array of tapes or strips 302A, 302B etc. of whatever width in parallel longitudinal relationship and then subjecting them to the processing conditions in the apparatus described herein. As shown in Figure 5, in one embodiment, each of overlaying strips or tapes 302A and 302B is 0.0025 inches in thickness and the molecules (schematically represented as triangles and circles) are in each of separate strips or tapes 302A and 302B. As shown in Figure 6, once the overlapping structure has been subjected to the process conditions described herein, the total thickness of the joint 304 is about 0.0032 inches, a total reduction of more than about 35% and the molecules have been intermingled, in this case most probably entangled to provide a joint 304 that exhibits a

higher strength than the parent material as well as a higher modulus. The thicknesses of strips or tapes 302A and 302B just mentioned are used for demonstration purposes only, it being clearly contemplated that thicker or thinner strips 302A and 302B could be equally well used to for the UHMWPE wide sheet described herein. More particularly, strips having thicknesses between about 0.0010 inches and 0.01 inches, for example, could be equally well used to form the wide sheet of the present invention assuming the availability of suitable calendaring equipment. Strips in the range of between about 0.0015 and about 0.007 inches in thickness are specifically preferred for use in the successful practice of the present invention. It should be noted that such thickness reduction in joint area 304 and the intermingling of the molecules of each of the parent strips or tapes 302A and 302B can only be accomplished with the application of the pressures described herein. Subjection of the overlapping structure to lower pressures, as described in the prior art, does not achieve the thickness reduction and molecular commingling of the present invention or the strength and modulus increases resulting therefrom. The attainment of these enhancements and their presence clearly and unequivocally distinguish the wide sheet described herein from those of the prior art.

24) Figures 10 and 11 depict cross-sectional views representing an alternative preferred embodiment of the UHMWPE wide sheet useful in the successful practice of the present invention. As shown in Figure 10, according to this embodiment, two strips 302A and 302B of UHMWPE are butted together. The processing of this butted configuration under the processing conditions described herein and in the apparatus described in the '094 application results in the structure shown in Figure 11 wherein each of strips 302A and

302B has undergone a degree of “side extrusion”, i.e. the longitudinal edges of each of the strips has been blended with the longitudinal edge of the abutting strip to form a joint area/volume 304 defined by the merger of the molecules of each of the member strips depicted as circles and triangles for differentiation purposes in these two Figures. This product wide sheet is fabricated by laying up an array of longitudinally abutting strips of UHMWPE and subjecting the array thus formed to the processing conditions described herein in an apparatus similar to that described in the ‘094 applicaiton with the exception that instead of overlaying neighboring strips of UHMWPE the strips are butted against each other prior to processing. Under these conditions, the abutting strips undergo side extrusion forcing the neighboring edges into each other to provide the structure depicted in Figure 11. As can be envisioned and as depicted in Figure 11, this wide sheet comprises an essentially flat sheet with little or no thickness difference in joint area/volume 304.

25) Referring now to Figures 1-3, the apparatus utilized in accordance with the present invention to obtain the wide ballistic sheet useful in the present invention comprises seven discrete zones 10-70 as depicted in Figure 1. Zone 10 is the feedstock payoff zone, zone 20 comprises a tension control zone that helps develop tension (other means are of course possible such as the inclusion of additional rollers), zone 30 is the initial and final alignment guide zone, zone 40 is a motor driven roll stand that imparts pulling energy to draw material through apparatus 1, zone 50 comprises the calender rolls that apply heat and pressure to bond the strips 01 of overlapped material, zone 60 comprises a motor driven roll stand that pulls the overlapped material from the calender and feeds it to the take up stand or zone 70.

26) Individual rolls of material 01 and 01' (shown as element 302 in Figures 5, 6 and 7) are mounted on shafts 12 and 12' to support them for unrolling and to place them in staggered relationship. The material on each of individual rolls 1 has an edge 3 and the edges 03 on staggered rolls 01 and 01' are oriented so as to overlap slightly as shown in the accompanying Figures. A resistance mechanism 14 is applied to rolls 1 to control their rate of unwinding.

27) As material 302 exits feedstock payoff zone 10 it is passed through a series of bars 20 (best seen in Figure 1) that serve to control tension as material 302 is pulled through the line by subsequent operations. As will be explained more fully below, tension control is very important to the successful practice of this method.

28) Upon exiting zone 20 material 302 enters zone 30 which comprises two sets of offset rolls 31 and 31' that include flanges 32 and 32' mounted upon adjustable shafts 33 and 33' that serve to direct the flow of material 302 into subsequent zone 40 and control the amount of overlap of material 302 as it enters this subsequent zone.

29) Zone 40 comprises a series of vertically offset rolls 40 and 40' that pull material 302 from feedstock rolls 01 and through zones 20 and 30. A motor 42 is provided to drive rolls 41 and 41'.

30) Zone 50 comprises a final set of guide rolls 31 including flanges 32 mounted on a shaft 33 which serve to provide final guidance of overlapped material 302 into calender zone 50. The overlapped materials at this point in the process and in accordance with this embodiment are shown generally in Figure 4. As shown in this Figure three input strips 1 of widths W1, W2 and W3 are overlapped a distance WT. WT may vary widely from a small fraction of an inch upwards to an inch or two. The amount of overlap is not particularly significant and does not materially affect the process or the product produced thereby. Within calender zone 50 are located calender rolls 51 and 51' that supply the requisite pressure to overlapped material 302 as specified elsewhere herein and exiting zone 50 is wide ballistic sheet 300 comprising overlapped and intimately bound sections of material 302 as shown in Figure 5. As depicted in Figure 3, a lift bar 55 driven by cylinder 54 is provided to lift top roll 51 to permit threading of overlapped material 302 between calender rolls 51 and 51'.

31) After exiting zone 50 wide ballistic sheet 300 enters zone 60 which comprises an offset set of pull rolls 61 which serve to draw material through apparatus 100 under tension as described elsewhere herein. A motor 62 is provided to drive rolls 60.

32) In zone 70 wide ballistic sheet 300 is taken up and rerolled onto a shaft 71 driven by motor 72.

33) Referring now to Figure 4, it can be seen that as material 01 enters the various guide rolls described hereinabove and more specifically guide rolls 31 proximate calender rolls

51 and 51', each has a specific width W1, W2 or W3 which are preferably all the same but could be different, and overlap as shown in Figure 4 and also shown in greater detail in Figure 7.

34) The processing conditions described herein, temperatures below the melting point of the UHMWPE strips, tensions in the range of from about 0.3 and about 5 grams/denier and pressures above about 300 pli, define an operating window whose parameters of temperature and tension are intimately interrelated. As is well known in the art of producing UHMWPE, as tension on a fiber or strip of UHMWPE the "melting point" i.e. the temperature at which the onset of melt can be detected, increases as tension increases on a fiber or strip. Thus while at a tension of 0.3 grams/denier a temperature of about 120°C may be below the melt point of the UHMWPE strips, at a tension of 5 grams/denier a temperature of 154°C may still be just below the melt point of the UHMWPE strips. Thus, this interrelationship of tension and temperature must be carefully considered and maintained in order to obtain the enhanced products of the present invention. The pressure element of the processing conditions is largely independent of the tension and temperature relationship just described. According to various preferred embodiments of the processing conditions of the present invention, temperatures in the range of from about 125 °C and 150 °C and tensions in the range of from about 0.4 and about 4.5 grams/denier are specifically preferred. The speed at which the process can be operated successfully is dependent solely upon the rate at which heat can be imparted to the UHMWPE strips. As long as the strips can be brought to the proper temperature prior to introduction into the calender rolls, the process will be effective. Such more rapid heating

could be through the use of a preheating oven, the use of larger calender rolls, multiple sets of calender rolls, the use of multiple calenders, etc.

35) UHMWPE wide sheet produced in accordance with the process described herein exhibit a remarkable degree of transparency, in excess of 30%, while those of the prior art prepared as described below exhibited the opacity of the parent strip materials. This is undoubtedly due to either the fact that at low temperatures the process of the prior art does not produce well consolidated or intimately commingled structures, thus, exhibiting the transparency of the parent material, while at higher temperatures melting occurs, as discussed in greater detail below, leading to the presence of voids in the melted areas that serve to diffuse light and result in increased opacity.

36) The specific adhesives tested and significant measured properties are presented in Table 1 below:

Table 1: Adhesives Tested for effectiveness in bonding Tensylon tape into a ballistic laminate:

Adhesive Code	Chemical Composition	Melt Temperatures (degrees C)	Measured Coat Weight (gsm)
A1	Polyamide	100 – 115	6.2
B1	Polyolefin	93 – 105	6.0
C1	Ethylene Vinyl Acetate Copolymer	98 – 112	4.7
D1	Polyurethane	70 – 100	16.7
E1	Ethylene Acrylic Acid Copolymer	88 – 105	N/A

F1	Polystyrene Isoprene Copolymer	N/A	6.0
G1	Polyamide	N/A	5.0
H1	Polyurethane	N/A	5.0

37) The adhesives tested included Polyethylene-PO4401 (A1), Polyethylene-PO4605 (B1), Polyethylene-DO184B (C1), Polyurethane-DO187H (D1), and Polyethylene-DO188Q (E1), which are all available from Spunfab, Ltd. of Cayahoga Falls, Ohio; Kraton D1161P (F1), which is available from Kraton Polymers U.S., LLC of Houston, Texas; Macromelt 6900 (G1), which is available from Henkel Adhesives of Elgin, Illinois; and Noveon-Estane 5703 (H1), which is available from Lubrizol Advanced Materials, Inc. of Cleveland, Ohio. Adhesives A1 through E1 were applied to the Tensylon tape by the laminator/fuser 20 depicted in Figure 1 of U.S. Patent Application Serial No. 11/881,863. Adhesives F1 through H1, which were dispersed in solvents, were coated on a release film and then transferred to one side of the UHMWPE tape.

38) The adhesive-coated unidirectional non-fibrous, high modulus, ultra high molecular weight polyethylene tape, commonly termed "unitape" and consisting of eight strips of UHMWPE tape fused at their edges, was then cut into 12-inch by 12-inch sheets. Figures 10 and 11 depict two sheets 460 and 462 of adhesive-coated unitape consisting of strips of UHMWPE tape 464 fused at joint areas 466. The joint areas 466 are depicted for clarity in describing the direction of orientation of the UHMWPE tape in Figure 10, it should be understood that the UHMWPE tape strips 464 are rendered substantially transparent when bonded as described herein therefore making the joint areas 466 appear homogenous

with the sheet. The bonding of non-fibrous, high modulus, ultra high molecular weight polyethylene tape is described in detail in U.S. Patent Application Serial No. 11/787,094, filed on April 13, 2007, which has been incorporated herein by reference. The top sheet 460 of adhesive-coated unitape is oriented at 90° with respect to the bottom sheet 462. An adhesive layer 468, shown as a transparent layer of adhesive in Figures 10 and 11, is bonded to each sheet 460 and 462 in the manner described above. As the adhesive is thermoplastic, the two sheets 460 and 462 of adhesive-coated unitape are pressed together with heat and pressure which causes the two sheets to bond together into a cross-ply sheet of non-fibrous, high modulus, ultra high molecular weight polyethylene UHMWPE with the bonded sheets cross-ply in the 0° and 90° direction.

39) To form a ballistic-resistant panel, cross-ply sheets of adhesive-coated non-fibrous, high modulus, ultra high molecular weight polyethylene were stacked until a stack of cross-ply non-fibrous, high modulus, ultra high molecular weight polyethylene of approximately 2.0 psf (pounds per square foot) was obtained. Several of the nominal 2.0 psf stacks were pressed at a pressure of 150 psi and several at a pressure of 3,000 psi. The press cycle included 30 minutes at a temperature of 250° F to 260° F and cooling under full pressure to below 120° F before release thereby forming ballistic-resistant panels of nominally 2.0 psf areal density.

40) The ballistic-resistant panels were then tested for ballistic resistance. Projectiles of 0.30 caliber FSP (Fragment Simulated Projectile) per MIL-P-46593A were fired at the 2.0 psf test panels to obtain ballistics properties of the panels bonded with the various

adhesives. The velocities in fps (feet per second) at which 50% of the projectiles failed to penetrate the target (V_{50}) were determined per MIL-STD-662F. Data for the resultant ballistic-resistant panels formed at 150 psi are shown in Table 2 and data for the resultant ballistic-resistant panels formed at 3,000 psi are shown in Table 3 below:

Table 2 – Data Results for Ballistic-resistant panels of UHMWPE tape formed with various adhesives at Molding Pressure 150 psi and Ballistic Test Results:

Adhesive Description	Adhesive ID	Adhesive Weight (gsm)	Adhesive (wt%)	Areal Density (psf)	Average 0.30 Cal FSP V_{50} (fps)
A1	Polyamide	5.93	10.4	2.01	1873
A1	Polyamide	3.10	5.7	1.88	1984
C1	Ethylene Vinyl Acetate Copolymer	5.93	10.4	2.03	1957
D1	Polyurethane	15.25	22.9	2.02	1818
E1	Ethylene Acrylic Acid Copolymer	5.93	10.4	2.02	1832
B1	Polyolefin	5.93	10.4	2.01	1937
B1	Polyolefin	3.10	5.7	2.05	1878
F1	Polystyrene-Isoprene Copolymer	7.40	12.6	2.01	2057
F1	Polystyrene-Isoprene Copolymer	5.70	10.0	2.07	2124
Dyneema HB2	Polystyrene-Isoprene	-	-	1.99	2275
Dyneema HB25	Polyurethane	-	-	2.00	2192

Table 3 – Data Results for Ballistic-resistant panels of UHMWPE tape formed with various adhesives at Molding Pressure 3,000 psi and Ballistic Test Results:

Adhesive Description	Adhesive ID	Adhesive Weight (gsm)	Adhesive (wt%)	Areal Density (psf)	Average 0.30 Cal FSP V₅₀ (fps)
A1	Polyamide	5.93	10.4	1.94	1915
C1	Ethylene Vinyl Acetate Copolymer	5.93	10.4	1.96	1963
B1	Polyolefin	5.93	10.4	1.96	2014
B1	Polyolefin	3.10	5.7	2.02	1970
F1	Polystyrene-Isoprene Copolymer	7.40	12.6	2.03	2242
F1	Polystyrene-Isoprene Copolymer	5.70	10.0	2.02	2136
Dyneema HB2	Polystyrene-Isoprene	-	-	2.00	2541
Dyneema HB25	Polyurethane	-	-	2.00	2386

41) A summary of the data suggests that the 3000 psi ballistic-resistant panels molded with adhesives A1, B1, and C1 rated slightly higher for ballistic performance than did the 150 psi panels. Adhesives B1 and C1 were essentially equal in performance. The V₅₀ results suggest that all of the test panels were acceptable for ballistic resistance of 0.30 caliber fragment simulated projectiles.

42) As the invention has been described, it will be apparent to those skilled in the art that the same may be varied in many ways without departing from the spirit and scope of the invention. Any and all such modifications are intended to be included within the scope of the appended claims.

What is claimed is:

1) A ballistic-resistant panel comprising a plurality of bonded, interleaved and angularly disposed layers of non-fibrous, high modulus, ultra high molecular weight polyethylene tape;

each of said layers of non-fibrous, high modulus ultra high molecular weight polyethylene tape comprising a plurality of tape strips longitudinally joined together in a sheet structure.

2) The ballistic-resistant panel of claim 1 wherein said plurality of bonded, interleaved and angularly disposed layers of non-fibrous, high modulus, ultra high molecular weight polyethylene tape are bonded through the application of heat and pressure.

3) The ballistic-resistant panel of claim 2 wherein the heat of bonding is at least 150 degrees F and the pressure of bonding is at least 150 psi.

4) The ballistic-resistant panel of claim 1 wherein the plurality of tape strips joined together in a sheet structure comprises partially overlapped or abutted strips of non-fibrous, high modulus, ultra high molecular weight polyethylene tape that define joints between adjoining strips wherein the thickness of the joints is less than about 80% of the thickness of the sum of the thicknesses of the adjoining strips that make up the joint.

5) The ballistic-resistant panel of claim 1 wherein the plurality of tape strips joined together in a sheet structure comprises an array of tape strips arranged side to side in a butt joint and bonded together by heat and pressure.

6) The ballistic-resistant panel of claim 1 wherein the plurality of tape strips joined together in a sheet structure comprises an array of longitudinally, partially overlapped strips of non-fibrous, high modulus, ultra high molecular weight polyethylene tape that define joints between overlapped strips wherein the thickness of the joints is less than about 80% of the thickness of the sum of the thicknesses of the adjoining strips that make up the joint.

7) The ballistic resistant panel of claim 1 further including a layer of adhesive between the layers of non-fibrous, high modulus, ultra high molecular weight polyethylene tape.

8) The ballistic resistant panel of claim 7 wherein the adhesive is selected from the group consisting of: polyamide, ethylene vinyl acetate, polyurethane, ethylene acrylic acid, polyolefin and polystyrene isoprene copolymer adhesives.

9) The ballistic-resistant panel of claim 7 wherein said plurality of bonded, interleaved and angularly disposed layers of non-fibrous, high modulus, ultra high molecular weight polyethylene tape are bonded through the application of heat and pressure.

10) The ballistic-resistant panel of claim 9 wherein the heat of bonding is at least 150 degrees F and the pressure of bonding is at least 150 psi.

11) The ballistic-resistant panel of claim 7 wherein the plurality of tape strips joined together in a sheet structure comprises partially overlapped or abutted strips of non-fibrous, high modulus, ultra high molecular weight polyethylene tape that define joints between adjoining strips wherein the thickness of the joints is less than about 80% of the thickness of the sum of the thicknesses of the adjoining strips that make up the joint.

12) The ballistic-resistant panel of claim 7 wherein the plurality of tape strips joined together in a sheet structure comprises an array of tape strips arranged side to side in a butt joint and bonded together by heat and pressure.

13) The ballistic-resistant panel of claim 7 wherein the plurality of tape strips joined together in a sheet structure comprises an array of longitudinally, partially overlapped strips of non-fibrous, high modulus, ultra high molecular weight polyethylene tape that define joints between overlapped strips wherein the thickness of the joints is less than about 80% of the thickness of the sum of the thicknesses of the adjoining strips that make up the joint.

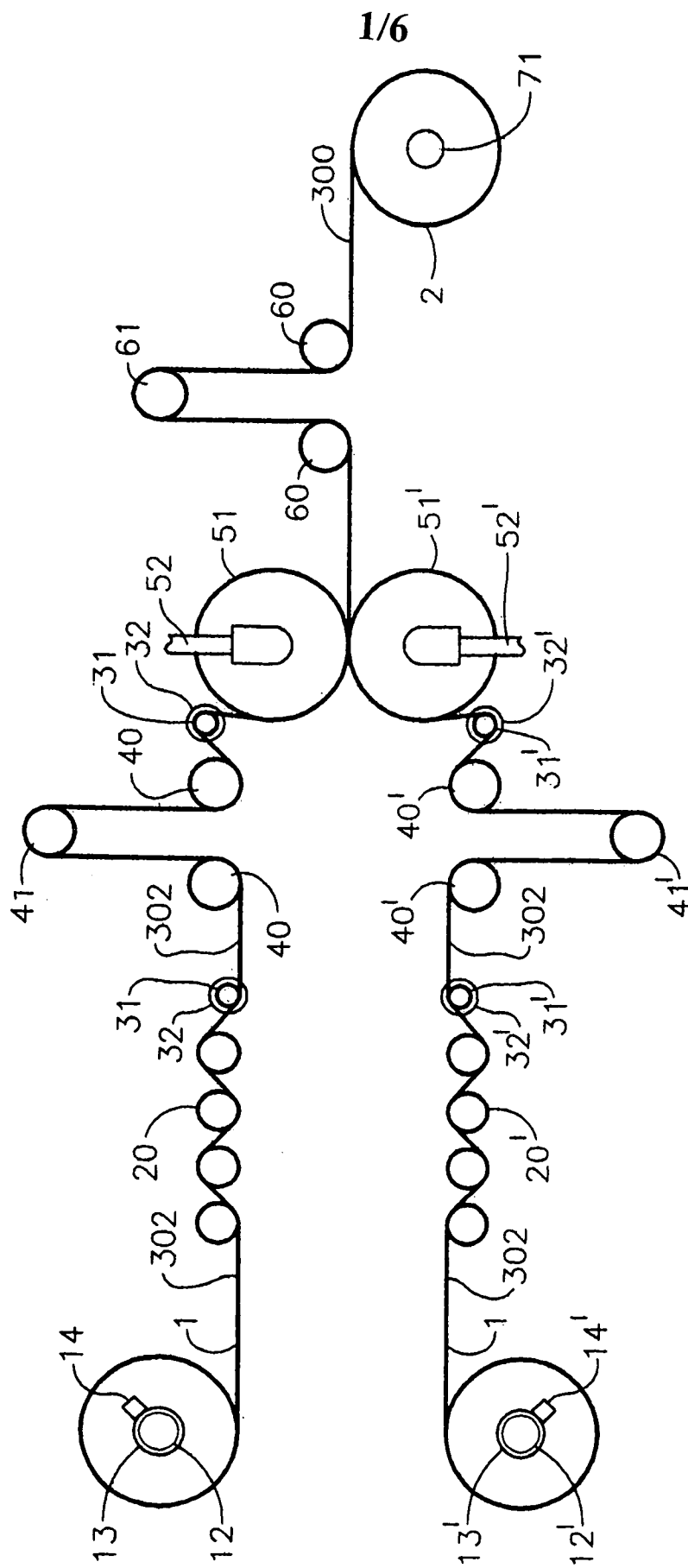


FIG. 1

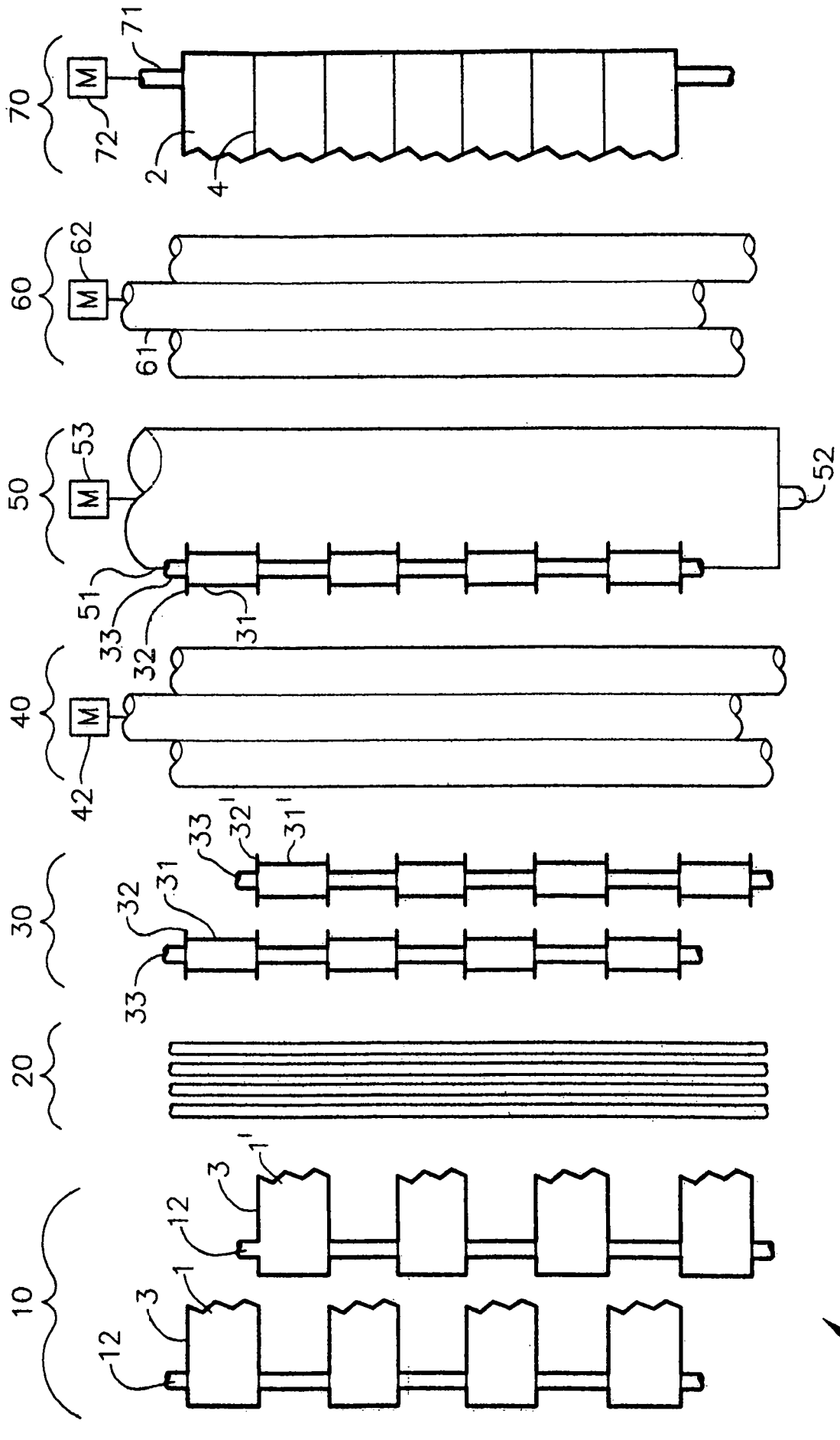


FIG. 2

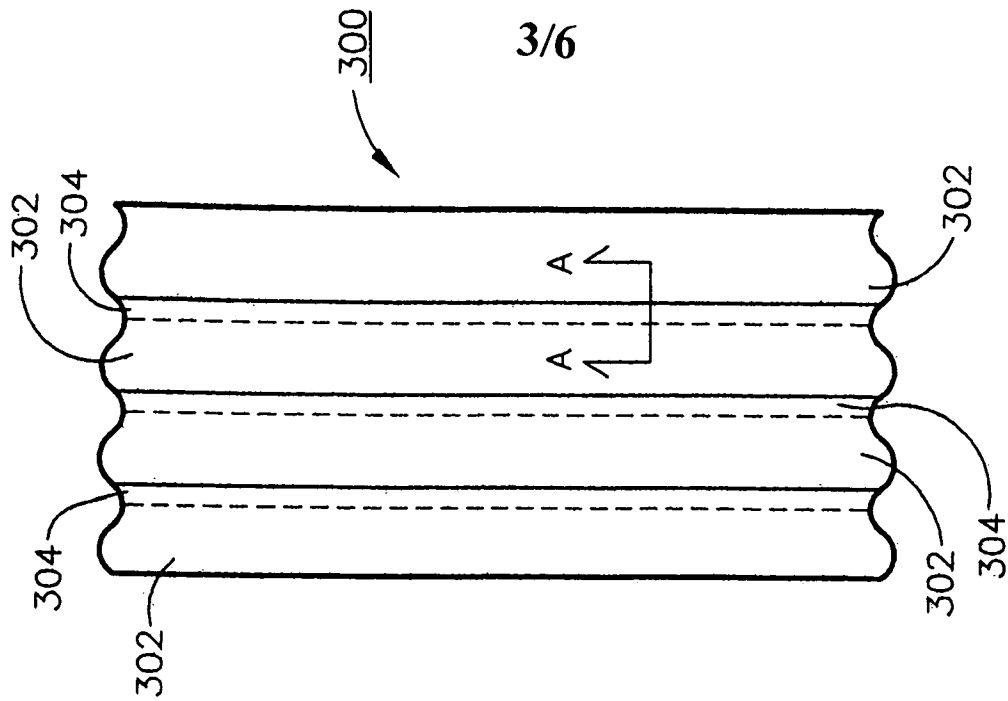


FIG. 7

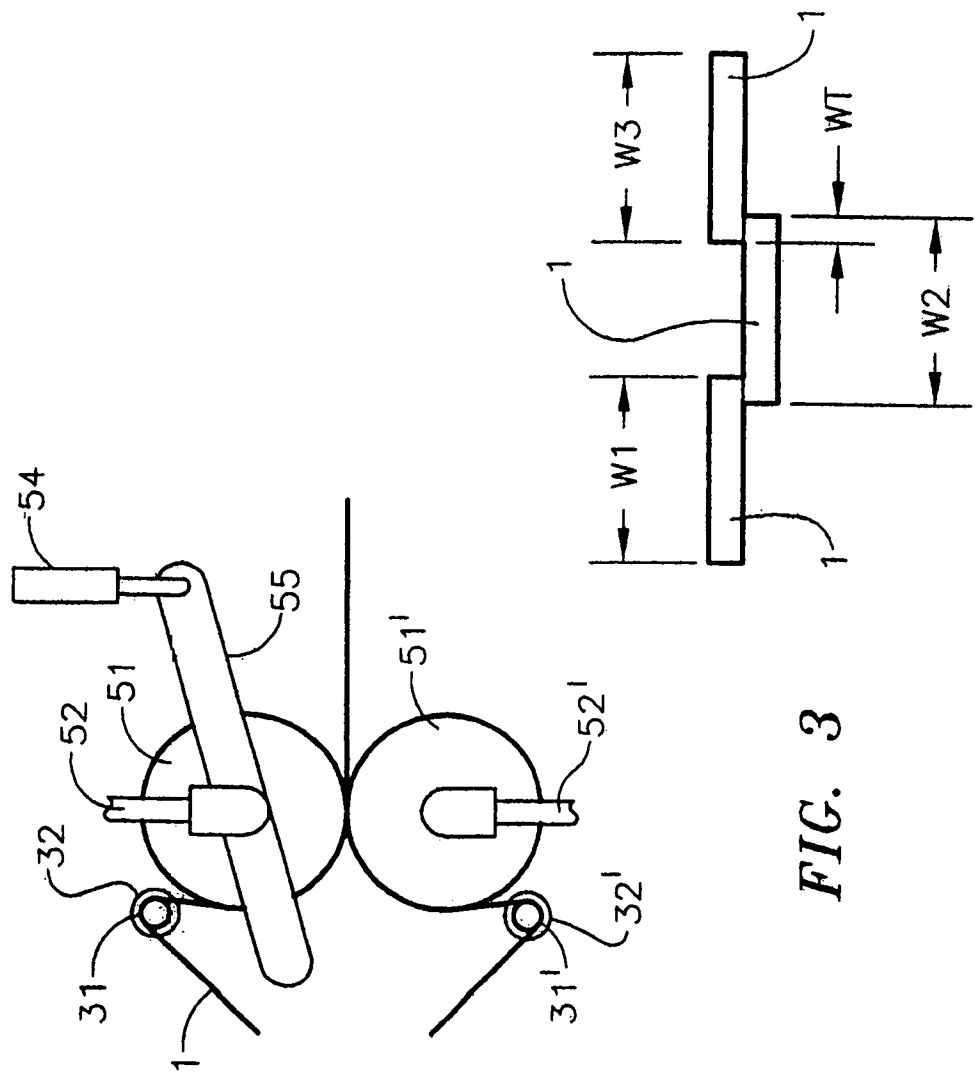


FIG. 3

FIG. 4

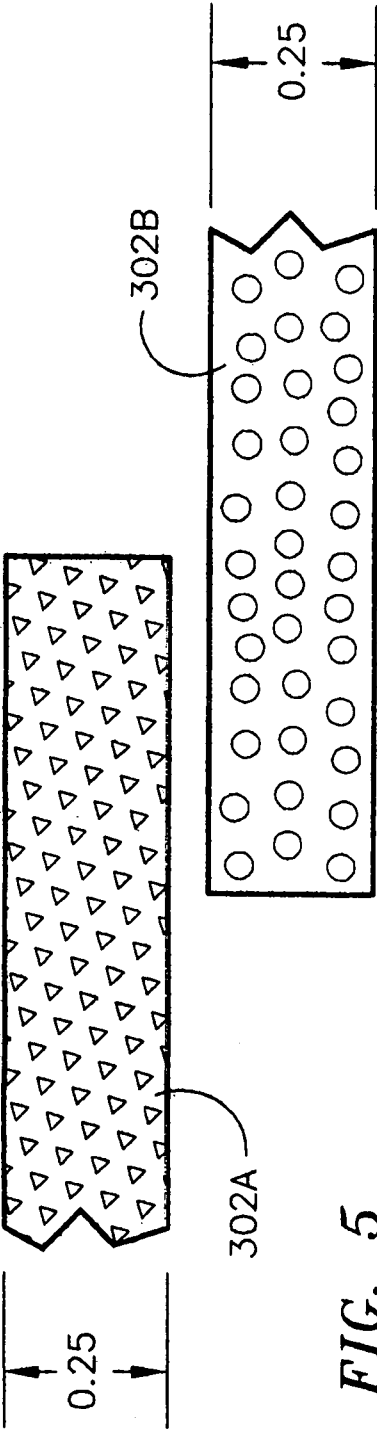


FIG. 5

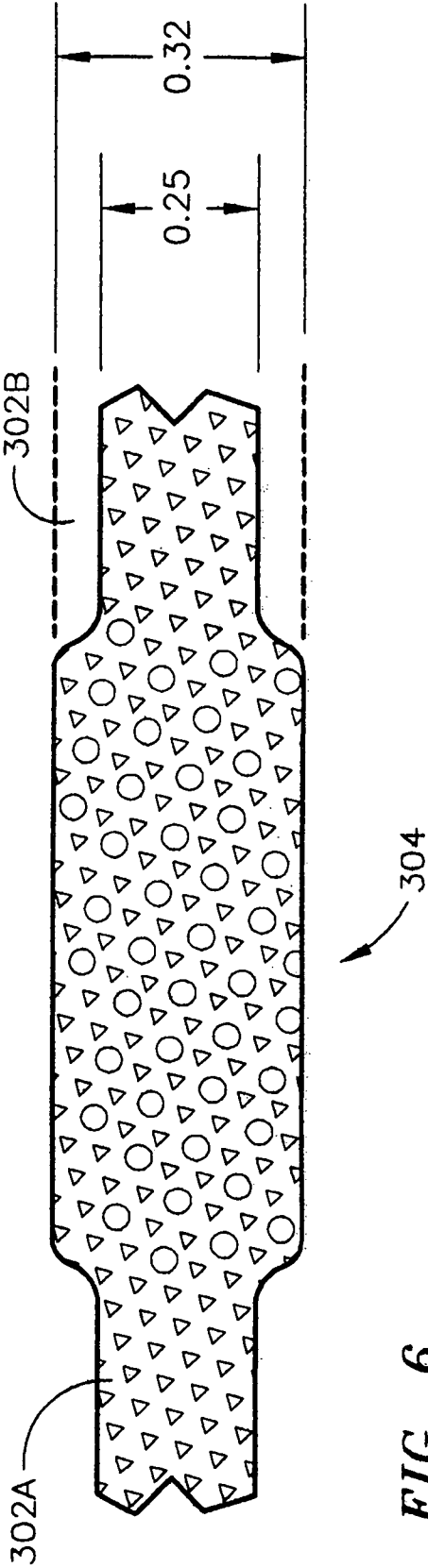


FIG. 6

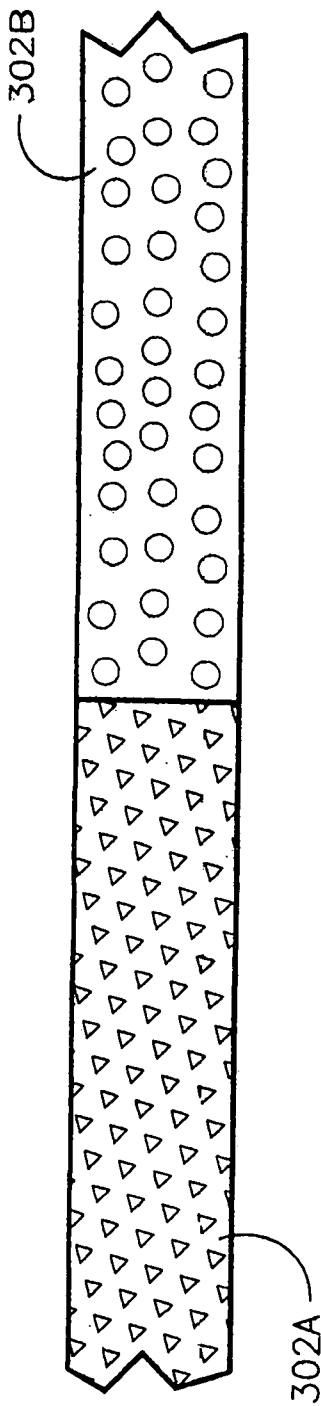


FIG. 8

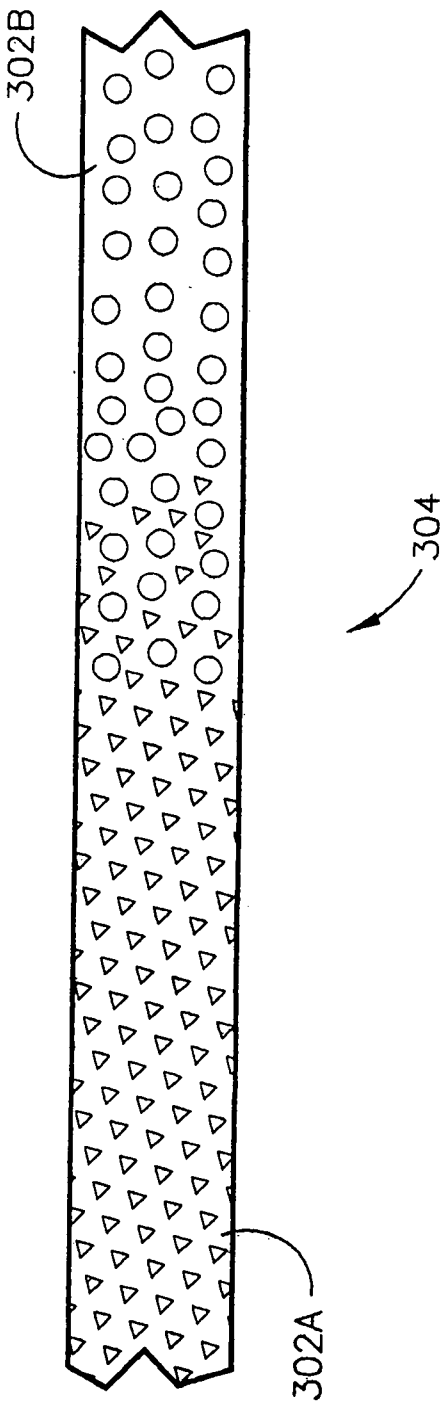


FIG. 9

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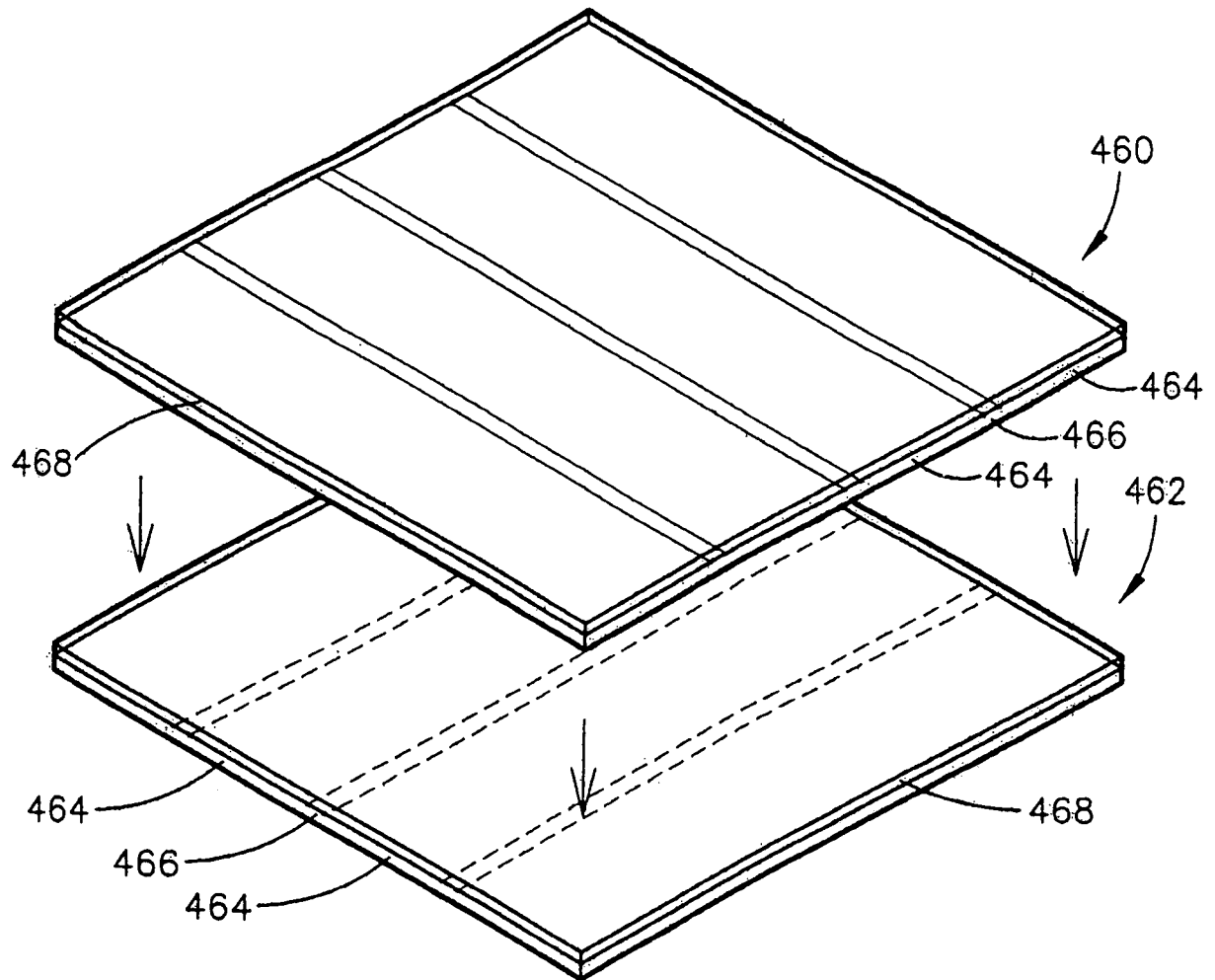


FIG. 10

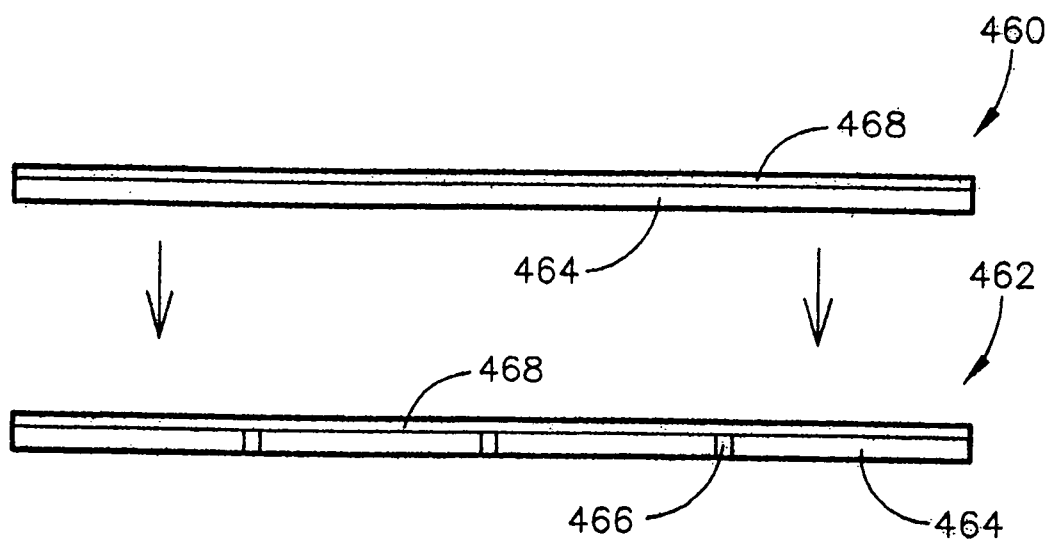


FIG. 11