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(54) Title: METHOD AND APPARATUS FOR DEFEATING HIGH–VELOCITY PROJECTILES

(57) **Abstract**

A method and apparatus for defeating high–velocity projectiles. A plurality of disks of equal size and having a thickness greater than 0.100 " are milled in a plurality of places. Each milled place having a radius of curvature approximately equal to the radius of curvature of the disk. The disks are then laid out in an imbricated pattern row by row such that each disk in a row is in substantially a straight line with the other disks in the row and overlaps a milled place of a disk in a row above its row and has its milled place overlapped by a disk in the row below its row. The imbricated pattern is then adhered to a flexible, high tensile strength substrate and overlaid by a second high tensile strength layer such that the imbricated pattern is enveloped between the substrate and the second layer. The envelope is then coupled to a soft body armor backing. In an alternative embodiment, a method and apparatus for defeating high–velocity projectiles. A plurality of disks of equal size comprised of fiber induced ceramic composites are provided. The disks are laid out in an imbricated pattern row by row such that each disk in a row is in substantially a straight line with the other disks in the row and overlaps a segment of a disk in an adjacent row. The imbricated pattern is then adhered to a flexible, high tensile strength substrate and overlaid by a second high tensile strength layer such that the imbricated pattern is enveloped between the substrate and the second layer. The envelope is then coupled to a soft body armor backing.

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METHOD AND APPARATUS FOR DEFEATING HIGH-VELOCITY PROJECTILES

BACKGROUND OF THE INVENTION

(1) Field of the Invention

The invention relates to protective wear. More specifically, the invention relates to flexible body armor designed to defeat high-velocity projectiles.

(2) Background

Advances in body armor are frequently related to development of improved materials from which the armor is formed. In recent years, ballistic resistant materials formed from high tensile strength fibers, such as aramid fibers or polyethylene fibers, have gone into common use in the field. Unfortunately, soft body armor, even with these advanced materials, has proven insufficient to thwart even armor-piercing pistol ammunition, sharp thrusting implements, and circular penetrators, all of which are now in common use.

To address this problem, various hard metal plating systems have been developed. One such system employs a number of titanium discs one inch in diameter and .032-.050 inches in thickness laid out in overlapping rows such that in the interior of a row, a disk overlaps its predecessor in the row and is overlapped by its successor in the row. Subsequent rows overlap their predecessor and are overlapped by their successor. The coin layout is then attached to a substrate such as adhesive impregnated aramid fabric. A second layer of adhesive impregnated aramid may be used to envelope the "plate" formed by the coins. This enveloped plate can be attached to conventional soft body armor over vital organs. It provides good flexibility and is thin enough to conceal.

While this overlapping of the coins has been shown to spread the force effectively to defeat most existing armor-piercing pistol rounds, sharp thrusting implements, and circular penetrators, unfortunately, rifle rounds

continue to tear through this plating structure, as well as the underlying soft body armor like a hot knife through butter. Thus, for protection from rifle rounds, users have been required to employ large rigid plates to shield the vital organs. These large plates are heavy and inflexible, and generally uncomfortable to use. Additionally, they are next to impossible to use in a concealed manner. Efforts to employ the coin design with thicker disks have failed to yield a commercially viable product to defeat rifle rounds. Thicker disks result in less flexibility and do not lay out well. The result is a plating structure thicker, no more flexible, and heavier than the solid plates discussed above. Wearer comfort is also a premium concern in body armor production. Accordingly, these limitations make such a structure impractical as a commercial product.

In view of the foregoing, it would be desirable to have a flexible armoring system that would defeat high-velocity projectiles, such as rifle rounds.

BRIEF SUMMARY OF THE INVENTION

A method and apparatus for defeating high-velocity projectiles is disclosed. A plurality of disks of equal size and having a thickness greater than .100" are milled in a plurality of places. Each milled place having a radius of curvature approximately equal to the radius of curvature of the disk. The disks are then laid out in an imbricated pattern row by row such that each disk in a row is in substantially a straight line with the other disks in the row and overlaps a milled place of a disk in a row above its row and has its milled place overlapped by a disk in the row below its row. The imbricated pattern is then adhered to a flexible, high tensile strength substrate and overlaid by a second high tensile strength layer such that the imbricated pattern is enveloped between the substrate and the second layer. The envelope is then coupled to a soft body armor backing.

In an alternative embodiment, a method and apparatus for defeating high-velocity projectiles is disclosed. A plurality of disks of equal size comprised of fiber induced ceramic composites are provided. The disks are

laid out in an imbricated pattern row by row such that each disk in a row is in substantially a straight line with the other disks in the row and overlaps a segment of a disk in an adjacent row. The imbricated pattern is then adhered to a flexible, high tensile strength substrate and overlaid by a second high tensile strength layer such that the imbricated pattern is enveloped between the substrate and the second layer. The envelope is then coupled to a soft body armor backing.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a cutaway schematic of a suit of body armor of one embodiment of the instant invention.

Figure 2 is a perspective diagram of the layout of disks in one embodiment of the invention.

Figure 3 is a diagram of an imbricated pattern adhered to a substrate.

Figure 4 is a diagram of enveloping the imbricated pattern between a substrate and an additional layer.

Figure 5 is a perspective view of a disk of an alternative embodiment of the invention.

Figure 6 is a sectional view of the disk of the embodiment of Figure 5.

Figure 7 is a perspective view of a disk of a second alternative embodiment of the invention.

Figure 8 is a cross-sectional view of the disk of the embodiment of Figure 7.

Figure 9 is a frontal view of one embodiment of body armor.

Figure 10 is a cutaway view of one embodiment of the body armor.

Figure 11 is a side cutaway cross-sectional view of one embodiment of the body armor.

Figure 12 is a perspective view of one disk embodiment.

Figure 13 is a perspective view of the disk embodiment of Figure 4 with an epoxy modified resin and Eglass coating.

Figure 14 is a sectional view of the disk embodiment of Figure 5 illustrating the coatings.

Figure 15 is a perspective view of one disk embodiment.

Figure 16 is a sectional view of one disk embodiment.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 is a cutaway schematic of a suit of body armor of one embodiment of the instant invention. The body armor 10 covers a user's torso and is designed to protect the vital areas from high-velocity projectiles. Through appropriately laying out disks in an imbricated pattern, the overall body armor 10 remains flexible and also provides good protection against high velocity projectiles. Unlike the 10 x 12 rigid plates of the prior art, the imbricated pattern can flex around body contours and is therefore considerably more comfortable and also more readily concealable. The imbricated pattern 12 is typically sandwiched between two layers of fabric 14 made of high tensile strength fibers, such as aramid fibers or polyethylene fibers. The fabric 14 should be tear and cut resistant and is preferrably ballistic grade material designed to reduce fragmentation. This fabric 14 can be adhesive impregnated, thus, the adhesive on the fabric adheres to the disks that compose the imbricated pattern 12 and retains their relative position. One or more additional layers of the fabric 14 may be added to the sandwich. This will be discussed further below.

Underlying the imbricated pattern 12 that is sandwiched between two or more layers of tear and cut resistant fabric layers 14 is conventional soft body armor 16. A high-velocity projectile is deemed defeated even if it penetrates the plating of the imbricated pattern and all fabric layers if it does not penetrate the underlying soft body armor or cause backside deformation of greater than 1.73", as backside deformation is defined by the National Institute of Justice (NIJ). Attachment straps, such as strap 18, couple a front panel of the body armor 10 to a back panel of the body armor 10 in a standard manner. Attachment strap 18 could be any conventional strapping common in the industry.

Figure 2 is a perspective diagram of the layout of disks in one embodiment of the invention. In this case, the disks are laid out from left

to right. Each subsequent row is also laid out left to right. It has been found that switching from left to right, then to right to left, creates weakness in the resulting pattern that often causes failure. Figure 2 shows only part of two rows of the ultimate imbricated pattern. Disks within each row form a substantially straight line. Because the disks overlap, each disk has a slight slope relative a line normal to the layout surface. Additionally, each disk is rotated slightly such that a line through the center of a row in conjunction with an axis bisecting the milled arc of the central milled place is not at a right angle. In one embodiment, this angle is approximately 60°. A typical disk 52 is shown raised above its eventual placement in the pattern 50. Disk 52 is typically of a high hardness material, having a hardness of greater than 450 Brinell. Many suitable materials exist, including high carbon steel, stainless steel, steel alloys, and various titanium alloys. A preferred material is marketed under the trademark Mars 300™, and is available from Creusot-Loure Industries, a division of Creusot Marrel of France. Mars 300™ typically has a hardness of 630-650 Brinell. Another suitable material is sold under the trademark BP 633™ by Astralloy of Birmingham, Alabama. Most suitable materials are sold in sheets. Mars 300™ is purchased in sheets having a thickness of approximately .168". The individual disks must be cut from the sheets. This can be accomplished by plasma cutting, laser cutting, or water jet cutting, depending on the material used. "Cutting" as used herein (when unmodified) refers generically to any technique by which a disk is produced.

In one embodiment, disk 52 is laser-cut using a conventional laser technology to ensure a uniform diameter and smooth edge as between multiple disks. Water jet cutting could be used but is not believed to be as good as laser cutting. Plasma cutting would also be possible but would then require additional deburring and smoothing steps to achieve the same edge smoothness. After cutting each disk 52 is milled, disk 52 is milled in three places--a left milled place 54, a central milled place 58, and a right milled place 56. This milling can be performed in any order.

In one embodiment, each milled place is milled in multiple passes. For example, the left milled place 54 is taken down to approximately half

the eventual mill depth. The same half depth milling is then performed on the right milled place 56 followed by the central milled place 58. Then a second pass is performed to bring the mill depth down to approximately its final depth. A final high speed polishing pass is then performed to ensure a smooth finish for each of the milled places.

Typically, disk 52 has a radius between 1/2" and 2". Longer radii reduce flexibility but also manufacturing cost. In a currently preferred embodiment, a 1" radius is employed. Depending on the material, disks having thicknesses between .080" and .187" may be used. The radius of curvature of each milled place is approximately identical to the radius of the disk 52. Thus, if disk 52 has a one-inch radius, each milled place, left milled place 54, central milled place 58, and right milled place 56 also has a 1" radius of curvature. The depth of the milling is typically .040"-.080" for disks between .100" and .187" in thickness.

Each milled place has a "mill distance." Mill distance is defined as used herein to be the perpendicular distance between the edge of disk 52 and the apex of the milled place 54, 56, 58. In one embodiment, the right and left milled places 54, 56 have the same mill distance which on a 1" radius disk is .540". The central milled place has a mill distance of .50 on a 1" radius disk. It is important that when laid out in the imbricated pattern, three disks so laid define an arc 60 into which an additional disk may be placed. Notably, a disk seated in arc 60 may only abut the milled edge 62 of the disks whose right and left milled place it overlays. This will depend on the depth of the milling. In one embodiment, the milled edge 62 has a slight slope as opposed to being exactly perpendicular to the milled surface. This reduces cracking of the disk during a ballistic event and reduces wear on the milling equipment.

While in one embodiment, all disks are identical to disk 52, this leads to a number of milled places along ending edges (e.g., the right edge and the bottom if a left to right layout is used or conversely, the left edge and bottom if a right to left layout is used). The pieces fit together neatly and there is no significant gap between overlapping disks. The overlap of the shown pattern has been found to effectively spread the force of a high-velocity

projectile hit to adjacent disks, thereby preventing penetration and backside deformation. The edges on which disks have milled places not overlapped by another disk are deemed outside the "zone of protection" provided by the armor.

Additionally, because of the slight tilt of each disk in the pattern, a perpendicular hit is very unlikely and some of the energy will be absorbed in deflection. Finally, during the ballistic event, the hardness of the disk material tends to expand or blunt the tip of the projectile, causing a further reduction in its piercing ability. Notably, the layout can be made in any shape so that the zone of protection conforms to the torso or other vital area.

In an alternative embodiment, special finishing disks may be used with fewer milled places to ensure that all milled places are overlapped by a full thickness disk. For example, a bottom row of disks may be milled only to allow overlap of an adjacent disk in the bottom row, e.g., only having a right milled place (for a left to right layout), and since no other disk will overlap the disks in the bottom row, this will avoid thin spots in the bottom row.

Figure 3 shows an imbricated pattern of disks 52 coupled to a substrate 80. As previously discussed, substrate 80 could be an adhesive impregnated polyethylene or aramid fiber fabric. Suitable fabrics include the fabric sold under the trademark SPECTRA® by AlliedSignal of Morristown, New Jersey, TWARON® microfiliment by Akzo-Nobel of Blacklawn, Georgia, SB31 and SB2, sold under the trademark DYNEEMA, by DSM of Holland, PBO sold under the trademark ZYLON® by Toyobo of Tokyo, Japan, KEVLAR® or PROTERA® by E.I. Dupont de Nemours & Company of Chattanooga, Tennessee. Other suitable fabrics will occur to one of ordinary skill in the art.

Some suitable substrates are available with an aggressive adhesive coating covered by a release paper. In addition to being aggressive, it is important that the adhesive once cured remains flexible to reduce separation of the disks and substrate during a ballistic event. The substrate

of a desired size may be cut and the release paper peeled back to expose the adhesive surface. The disk can then be laid out directly onto the adhesive which retains them in position relative to one another. Because the substrate is flexible and the disks flex about their intersection, the combined unit is flexible. Alternatively, the pattern may be laid out and the substrate adhered over the top.

As shown in Figure 4, the next step is to place another layer of this adhesive coated flexible substrate on the other side of the hand laid coins to secure them in a flexible position that does not change when the panel is flexed, such that although each coin will pivot off the adjacent coins, the actual position of each coin remains substantially in the same place it was laid. This second layer of adhesive fabric used to envelop the imbricated pattern provides further staying power, thereby reducing the risk that a disk will shift and the body armor will fail.

The NIJ defines various levels of threat. A level three threat is a full metal jacket 7.62 x 51 millimeter 150 grain round traveling at 2700-2800 feet/second. It has been found that the above-disclosed invention will defeat level three and all lesser threats. Additional layers of the adhesive coated flexible substrate material may be added to either side in any proportion (i.e. it is within the scope and contemplation of the invention to have more substrate layers on one side of the plate than the other side of the plate) in multiple layers to achieve different performance criteria. Some situations benefit from allowing the coins to move slightly during the ballistic event, while others make it desirable that the coin remain as secure in place as possible.

In an alternative embodiment of the invention, a "dry" high tensile strength flexible substrate is provided. It is then coated with a flexible bonding agent, for example, a silicon elastomer resin. The disks may then be laid out as described above. The bonding agent is then cured to flexibly retain the relative locations of the disks. A similarly coated layer can be used to sandwich the plate from the opposite side. It is also within the scope and contemplation of the invention to use one layer with a flexible bonding agent while a facing layer is of the peel and stick variety described

above. As used herein, "adhesive impregnated substrate" refers to suitable flexible high tensile strength material having an adhesive disposed on one side, whether commercially available with adhesive in place or coated later as described above.

In yet another embodiment, an adhesive impregnated substrate is created by either above described method and the (sandwiching) layer is non-adhesive and merely coupled to the underlying substrate about the periphery of the plate. This will somewhat degrade the retension of the disk as compared to sandwiching between adhesive layers. Accordingly, this configuration will not survive as many hits and the front layer attached about the periphery serves primarily as a spall shield.

Figure 5 is a perspective view of a disk of a second alternative embodiment of the invention. In this embodiment, a flat disk is prepared in the normal manner and then curved slightly about an axis bisecting the arc of the central milled place. The bend will typically range from 2° to 15° off the horizontal, depending on the dimensions and curvature of the area to be protected by the armor. This embodiment is most suitable where large disks, e.g., having a radius of 2", are used as the slight curve, allowing the disks to better match the contours of the body. This is desirable with large disks because the larger disks imply reduced flexibility of the overall assembly. Therefore, from a comfort standpoint, it is desirable to have a disk curved to accommodate body contour and motion. For disks of a radius 1" or less, such bending is deemed unnecessary and undesirable. **Figure 6** is a cross-sectional view of the disk of the embodiment of Figure 5.

Figure 7 is a perspective view of a disk of an alternative embodiment of the invention. In this embodiment, the disk is prepared as described above. After milling but prior to layout, a press is used to concave the disk from the backside which causes the disk to be convex in the direction of the milled surface. **Figure 8** is a sectional view of the disk of the embodiment of Figure 7. In this view, the concavity is clearly evident. This disk design may have improved deflection characteristics over the flat disk and also may improve comfort for some wearers.

Figure 9 is a frontal view of a suit of body armor as worn in one embodiment of the instant invention. The body armor 110 covers a user's torso and is designed to protect the vital areas from high-velocity projectiles. Flaps 120 on the body armor extend around the wearer's body to extend protection to the wearer's sides. In one embodiment the body armor wraps around a segment of the wearer, for instance the torso, providing substantially uniform armor protection in a enveloping circumference.

Figure 10 is a cutaway frontal view of one embodiment of a suit of body armor. Disks 152 are arrayed in an imbricated pattern to cover vital areas where the body armor is worn. Unlike the 10 x 12 rigid plates of the prior art, the imbricated pattern can flex around body contours and is therefore considerably more comfortable and also more readily concealable. Each disk 152 is formed of a high hardness material. In one embodiment, each disk is discus shaped having a maximum thickness in the center of the disk and declining in thickness towards the outer edge by providing one or more downwardly inclined surface segments. In one embodiment, the thickness of the discus shaped disk declines in a uniform downward inclined slope from the center towards the outer edge. In another embodiment the discus shape has an internal circumference within which the disk is uniformly thick and slopes uniformly downward between the internal circumference and the circumferential edge of the disk.

Typically, the edge thickness will be approximately one-half the thickness in the center. As such, when laid out in the imbricated pattern the disks exhibit a pivot capability which allows on the order of 60% greater flexibility than metal plates or existing coin arrangements. Many such suitable ceramic materials exist which are also of relatively lighter weight when compared to steel or other high hardness metals.

The tapering design intrinsic to the discus shape of one embodiment of the invention renders the disk surface non-planar, providing a slope to deflect ballistic impacts as compared with a uniform flat planar surface. In this regard, the ceramic composite material can be sintered and/or molded into a homogenous ballistic grade discus shape more easily and less expensively than can a metal disk, which must either be lathed or tooled to

produce a similar tapering discus form. However, discus shaped metal disks are within the scope and contemplation of the invention. Through appropriately laying out disks in an imbricated pattern, the overall body armor 110 remains flexible and also provides good protection against high velocity projectiles.

Additionally, the lighter weight and greater flexibility of the ceramic composite as compared to prior art protection from high velocity projectiles, allows for greater mobility and range of motion by the wearer. For instance, body armor vests composed of imbricated ceramic disks of ballistic grade hardness and fracture toughness may wrap entirely around a segment of the wearer, for instance the torso, extending disk protection up to 360 degrees about the wearer. The lighter ceramic material also avoids pronounced negative buoyancy of high hardness metal coins or plates typical of prior art body armor. This provides for climbing or swimming uses in the field for which prior art body armor is not suitable.

In this embodiment also, to arrange the imbricated pattern, the disks are laid out from left to right. Each subsequent row is also laid out left to right. It has been found that switching from left to right, then to right to left, creates weakness in the resulting pattern that often causes failure. Disks within each row form a substantially straight horizontal line. Because the disks overlap, each disk lies on a slight tilting slope relative to a line normal to the horizontal layout surface. In one embodiment, this slight slope of the disks complements their inclined discus shape to increase the probability of impact deflection.

After the disks are laid out from left to right and top to bottom and sandwiched between a pair of adhesive layers, the entire pattern is inverted for assembly into body armor. It has been found that the majority of threats arrive at a downward trajectory. Thus it is desirable that each row of disks overlap the row below it as the armor is worn. It is, however, within the scope and contemplation of the invention to lay out the disks in an alternative order, e.g. right to left, bottom to top. It is also contemplated that inverting the imbricated pattern in the course of assembling the body armor may be connected such that each row overlaps the row above it.

A number of possible ceramic composites have been found suitable as high hardness materials for the disks. These include fiber induced ceramics sold under the trademarks SINTOX® FA and DERANOX® by Morgan Matroc, Ltd. of Bedforshire, England. In particular, SINTOX® FA alumina oxide ceramic and DURANOX® D995L, for a zirconia toughened alumina oxide ceramic composite, composed of approximately 88% by weight alumina plus approximately 12% by weight transformation toughened zirconia (TTZ), have proven suitable ceramic composites.

While alumina based composites are preferred, other bases may be utilized to form the ceramic composite including barium titanate, strotium titanate, calcium zirconate, magnesium zirconate, silicon carbides and boron carbides. As indicated, these potential ceramic bases are not limited to oxide ceramics but also include mixed oxides, non-oxides, silicates as well as MICATHERM® ceramics, (the latter being a trademark for inorganic thermoplastic materials sold by Morgan Matroc, Ltd. of Bedforshire, England).

Suitable ceramic composites would have relatively high hardness and fracture toughness. Typically, such materials would have at least approximately 12 GPa in hardness and at least 3.5 MPa $m^{1/2}$ in fracture toughness in order for the armor to withstand a level three ballistic event as defined by the National Institute of Justice (NIJ). A level three threat is a full metal jacket 7.62x51 mm 150 grain round traveling at 2700-2800 ft./sec. Ultimately, hardness and fracture toughness levels will depend on the type of ceramic composite employed. For exemplary embodiments of the present invention using alumina bases, the fracture toughness minimum for alumina would be 3.8 MPa $m^{1/2}$ and 4.5 MPa $m^{1/2}$ for zirconia toughened alumina. The hardness for alumina would be in the approximate range of 12 to 15 GPa, and for zirconia toughened alumina, the hardness would be at least approximately 15 GPa.

In certain instances, the ceramics employed may be supplemented by the addition of a toughening agent such as toughened metallic oxides. In one embodiment, TTZ is added to the alumina base. The inclusion of metallic oxides increase the strength of the resulting ceramic composite and

resist disassociation of the disk upon impact during a ballistic event. For alumina based ceramic composites, the range of TTZ percentage by weight for suitable ballistic grade ceramics would be between 0.05% and 20%. In one embodiment the percentage of TTZ by weight to the alumina base is approximately 12% of the composite.

The ceramics are mixed in ways commonly known in the art. Sintering and molding, including injection molding, methods to form the disk are well known in the art. In one embodiment, the disks may be formed by injection molding and then pressing to the desired shape. Once formed, certain embodiments of the disks are then encompassed with a containment wrap material. This material provides greater integrity to the disk and increases its fracture toughness, consequently enhancing its ability to absorb the impact of ballistic projectiles without disassociation. In one embodiment, this wrap is a glass fiber wrap adhered by an adhesive substrate. Suitable glass fiber materials include Eglass and S-2 Glass available from Owens Corning Fiberglas Technology, Inc. of Summit, Illinois. Suitable adhesives include modified epoxy resins. The containment wrap and epoxy resin substrate can be applied to the disk by autoclaving, or in other ways known to the art. Strength, cohesion and structural integrity may also be imparted by overlaying the disk surface with aramid fibers, layered or cross-laid on an adhesive substrate.

Typically, disk 152 has a radius between 1/2" and 1". Longer radii reduce flexibility but also manufacturing cost. In a current embodiment, a 1" radius is employed. Each disk tapers in thickness varying between its center region (where the thickness is at its maximum) and its edge (where the thickness is at a minimum). Maximum and minimum thicknesses will vary according to the level of ballistic threat to be defeated. For instance, to defeat a high velocity rifle ballistic threat, a maximum thickness of 3/8" in the center tapering to 3/20" minimum thickness at the edge may be used. A low velocity rifle threat (or a high velocity pistol threat) may only require a thickness of between 1/8" (maximum) and 1/10" (minimum). In one embodiment, the discus shaped disks have a center thickness of approximately 1/4" and an edge thickness of 1/8".

The overlap of the imbricated placement pattern has been found to effectively spread the force of a high-velocity projectile hit to adjacent disks, thereby preventing penetration and backside deformation. Additionally, because of the slight tilt of each overlapping disk in the imbricated pattern, a perpendicular hit is very unlikely and some of the energy will be absorbed in deflection. In the discus embodiment, the tapering of thickness, forming a non-planar inclined surface renders a perpendicular strike extraordinarily unlikely.

Figure 11 shows an imbricated pattern of disks 152 coupled to a substrate. As previously discussed, substrate could be an adhesive impregnated polyethylene or aramid fiber fabric. The same fabrics discussed above are suitable for use with the ceramic discs. Layout on the adhesive substrates is also analogous.

Figure 12 is a perspective view of a disk. In this embodiment, the disk has a discus shape of varying thickness, 1/4" in the center tapering with a uniform slope to 1/8" at the circumferential edge. In an imbricated pattern, edges of adjacent disks will overlap, creating areas of significant thickness having multiple disk layers. Ordinarily, this pattern will not overlap the center, or thickest region, of the disk. Thus, a projectile striking the disk pattern at any point will impact either a singular disk near its thickest region, or multiple layered disks at least as thick, and likely thicker, than the thickest region of the singular disk. Moreover, the slope of the discus shape between areas of varying thickness discourage any perpendicular ballistic impact.

Figure 13 shows a perspective view of a disk after application of a containment wrap. As noted above, this wrap may be a fiberglass or aramid fiber composite adhered to a substrate which may be a modified epoxy resin. The wrap imparts greater fracture toughness and hardness, reducing disk shatter and disassociation in response to a ballistic event.

Figure 14 shows a cross section of a disk illustrating its discus shape. The layers of adhesive 122 and containment wrap 124, as noted above, are evident.

Figure 15 is a perspective view of a disk of an alternative embodiment of the invention. In this embodiment, formation of the disk is substantially as described above, varying only in the slope of the end result. While varying in thickness from the center to the edge, the slope of tapering is not uniform, leaving a more pronounced bulging center having a domed shape. This leaves the surface area extending from the circumference edge to the domed center substantially planar. This embodiment allows for the disks to have a greater overlapped surface area, increasing the surface area in which a projectile would encounter multiple layers of disk. However, the substantially planar region increases the probability of a perpendicular strike. The domed disks can be laid out in an analogous manner to that described above and assembled into body armor capable of defeating level three threats.

Figure 16 is a side view of the alternative embodiment shown in Figure 6.

In the foregoing specification, the invention has been described with reference to specific embodiments thereof. It will, however, be evident that various modifications and changes can be made thereto without departing from the broader spirit and scope of the invention as set forth in the appended claims. The specification and drawings are, accordingly, to be regarded in an illustrative rather than a restrictive sense. Therefore, the scope of the invention should be limited only by the appended claims.

CLAIMS

What is claimed is:

1. A method of making a body armor to defeat a high-velocity projectile, the method comprising:

providing a high hardness material sheet;

cutting a disk having a radius; and

milling the disk in a plurality of places each having a radius of curvature equal to a radius of curvature of the disk.

2. The method of claim 1 wherein the sheet has a hardness greater than approximately 450 Brinell, and one disk a radius in the range of approximately 1/2" to approximately 2".

3. The method of claim 1 further comprising:

repeating the cutting and milling a plurality of times to produce a plurality of milled disks;

laying out the plurality of milled disks in an imbricated pattern; and

adhering a high tensile strength substrate to a first side of the imbricated pattern.

4. The method of claim 3 wherein in the imbricated pattern a first disk of the plurality is overlapped by three additional disks of the plurality, one in each milled place such that each milled place is substantially entirely covered by a full thickness portion of the overlapping disk.

5. The method of claim 2 wherein the material sheet has a thickness in the range of approximately .100" to .187".

6. The method of claim 3 further comprising:

enveloping the imbricated pattern between the substrate and a second layer of flexible, high tensile strength material; and

coupling the substrate and imbricated pattern to a soft body armor backing.

7. The method of claim 1 further comprising:

curving the disk about an axis intersecting a mill arc of one milled place.

8. The method of claim 1 further comprising:

pressing the disk to be convexed toward a surface including the milled places.

9. The method of claim 3 wherein laying out comprises:

placing a subset of the plurality of disks in a substantially straight row originating from a first direction with each disk rotated slightly such that an axis bisecting a central milled place is not at a 90° angle with a central axis of the row; and

placing successive overlapping rows originating from the first direction.

10. An apparatus comprising:

a first disk of material having a hardness, the disk having a radius and a thickness, the disk milled in a plurality of places, each milled place having a radius of curvature approximately equal to the radius of the disk, each specific milled place having a mill distance from an apex of the milled arc to the edge of the disk.

11. The apparatus of claim 10 wherein the hardness is greater than 450 Brinell, the radius is in the range of .5" to 2", and the thickness is in the range of approximately .100" to .187".

12. The apparatus of claim 10 wherein the disk is approximately one inch in radius and the mill distance for a right milled and left milled place being approximately .54" and the mill distance for a central milled place being approximately .50".

13. The apparatus of claim 10 further comprising:

a plurality of additional disks substantially identical in dimension to the first disk; and

a tear and cut resistant adhesive substrate adhering the disks in an imbricated pattern.

14. The apparatus of claim 13 wherein the plurality of milled places include a right milled place, a left milled place, and a central milled place, and wherein the imbricated pattern is such that a first disk is overlapped in the right milled place and left milled place by a second disk and a third disk, respectively, and the left milled place of the second disk and the right milled place of the third disk defined in conjunction with the central milled place of the first disk an arc into which a fourth disk is seated, such that the fourth disk overlaps the central milled place of the first disk, the left milled place of the second disk, and the right milled place of the third disk.

15. The apparatus of claim 9 further comprising:

a soft body armor backing coupled to the substrate.

16. The apparatus of claim 13 wherein a 7.62 x 51 mm 150 grain full metal jacket projectile traveling 2700-2800 feet/second will not penetrate the soft body armor backing and causes less than 1.73" of backside deformation.

17. The apparatus of claim 10 wherein the disk is curved about an axis intersecting one milled arc.

18. The apparatus of claim 10 wherein the disk is convex in a direction of a surface containing the milled places.

19. The apparatus of claim 13 wherein a first subset of the plurality are arranged in a first row with each successive disk of the first subset overlapping a milled place of a preceding disk of the first subset and a second subset of the plurality are arranged in a second row such that the second row overlaps the first row and each successive disk of the subset overlaps a milled place and a preceding disk of the second subset and wherein the first row and second rows both originate from a same direction.

20. An apparatus comprising:

A discus shaped disk used in body armor, having a radius, a first inclined surface co-extensive with a segment of the radius and a thickness.

21. The apparatus of claim 20 wherein the disk comprises a ceramic material.

22. The apparatus of claim 20 wherein the disk first inclined surface has a substantially uniform downward slope from a center of the disk coextensive with a portion of the radius.

23. The apparatus of claim 20 wherein the fiber induced composite ceramic material comprises alumina and has a hardness of at least 12 GPa, a fracture toughness of at least 3.8 MPa - $m^{1/2}$.

24. The apparatus of claim 20 wherein the disk further comprises a fiber induced ceramic comprising an alumina and toughened metallic oxide composite.

25. The apparatus of claim 24 wherein the toughened metallic oxide is transformation toughened zirconia.

26. The apparatus of claim 25 wherein the transformation toughened zirconia is approximately 12%, by weight, of the disk.

27. The apparatus of claim 20 wherein the disk further comprises a containment wrap coupled to the first inclined surface.

28. The apparatus of claim 27 wherein the containment wrap comprises:

an adhesive substrate coat; and,

glass fiber material overlaying the adhesive substrate.

29. The apparatus of claim 27 wherein the containment wrap comprises:

an adhesive substrate coat; and,

aramid fiber overlaying the adhesive substrate.

30. The apparatus of claim 20, further comprising:

a plurality of additional disks substantially identical in dimension to the first disk, the plurality of disks arranged in an imbricated pattern;

a tear and cut resistant adhesive substrate adhering the disks in an imbricated pattern.

31. The apparatus of claim 30, wherein the imbricated pattern comprises a plurality of substantially linear horizontal rows of disks.

32. The apparatus of claim 31, further comprising:

a soft body armor backing coupled to the substrate.

33. The apparatus of claim 32, wherein the apparatus extends around a wearer such that the imbricated disk pattern protects the wearer in more than a 180 degree arc.

34. The apparatus of claim 32 wherein the apparatus withstands a level three ballistic event.

35. A disk used in body armor having a radius, a concentric dome coextensive with a portion of the radius, and a substantially flat surface circumferentially surrounding the dome.

36. A method for making body armor to defeat a high-velocity projectile, the method comprising:

providing a plurality of ceramic disks having an inclined surface;

laying out the plurality of disks in an imbricated pattern on a layout surface;

adhering a high tensile strength substrate to a first side of the imbricated pattern.

37. The method of claim 17, wherein laying out comprises;

placing a subset of the plurality of disks in a substantially straight horizontal row originating from a first horizontal direction;

placing successive overlapping substantially straight horizontal rows originating from the first direction.

38. The method of claim 36, wherein the imbricated pattern comprises;

overlapping each disk upon a successive disk so that each disk tilts from a horizontal plane defined by the layout surface.

39. The method of claim 36, further comprising the step of encompassing a surface of the disks with a containment wrap.

40. The method of claim 36, further comprising the step of adhering a glass fiber overlay to a surface of the disks.

41. The method of claim 36 further comprising the step of adhering an aramid fiber overlay to the surface of the disks.

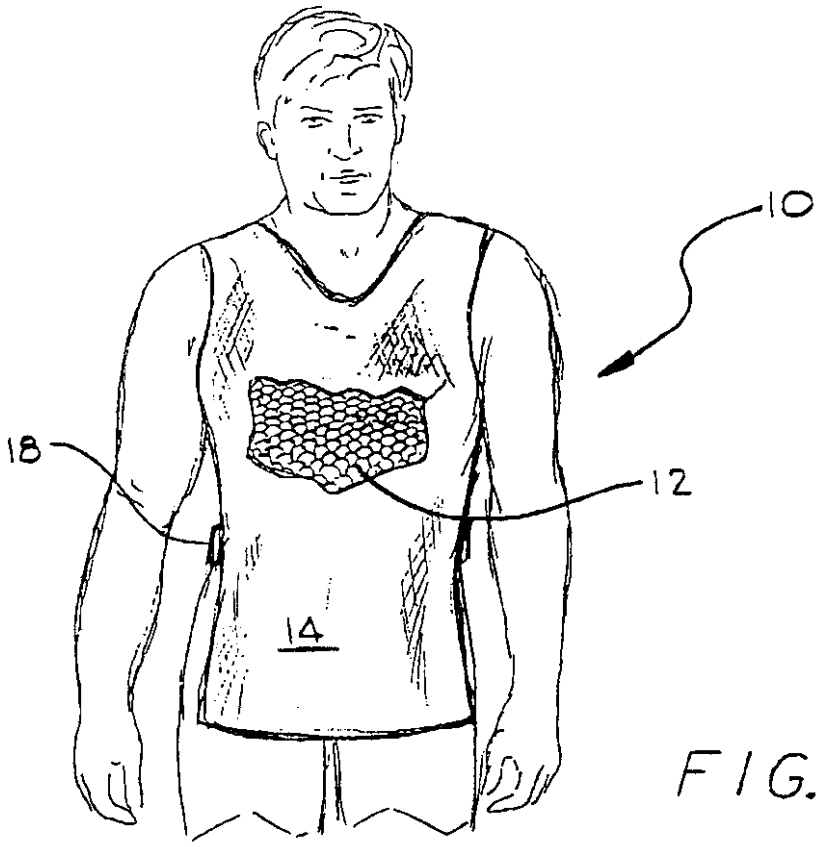

FIG. 1

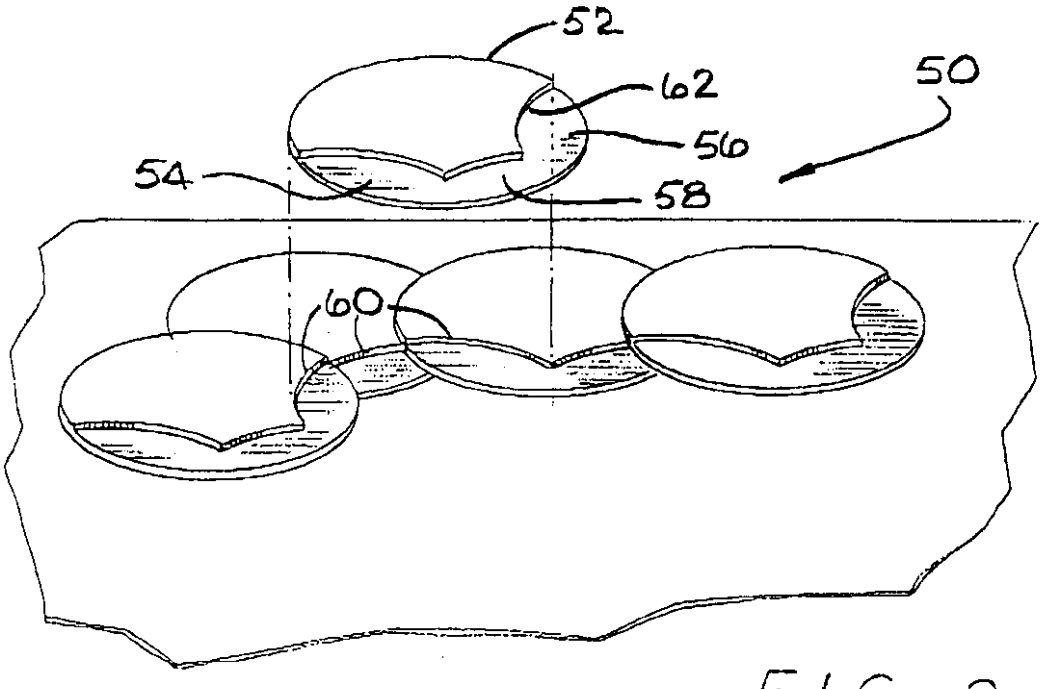

FIG. 2

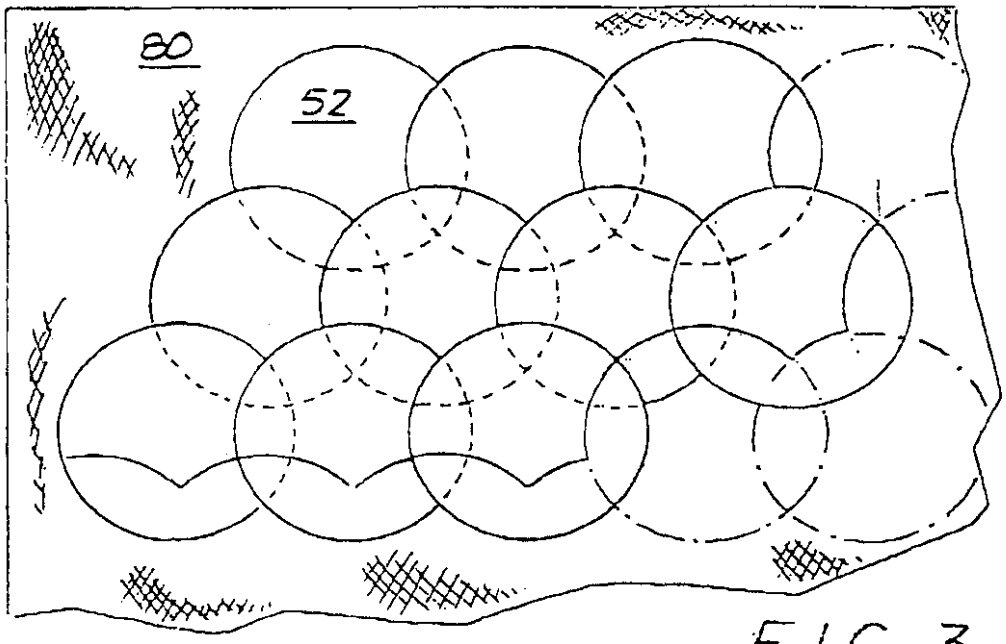

FIG 3

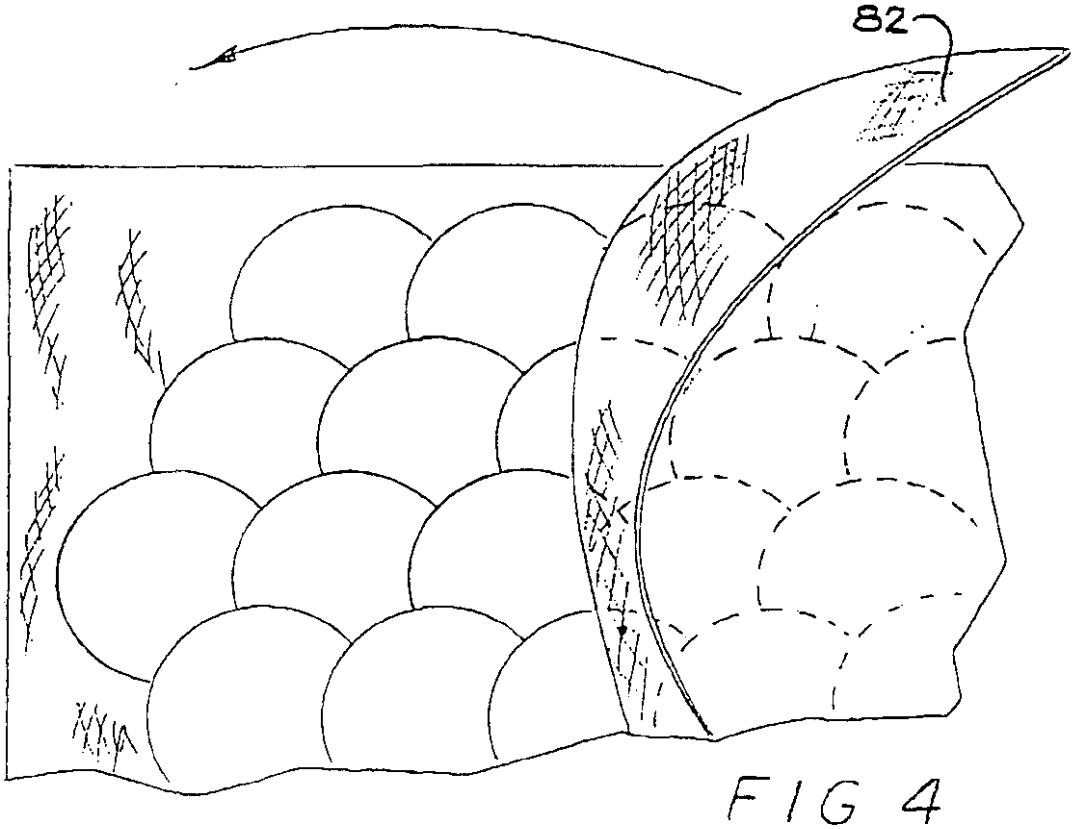

FIG 4

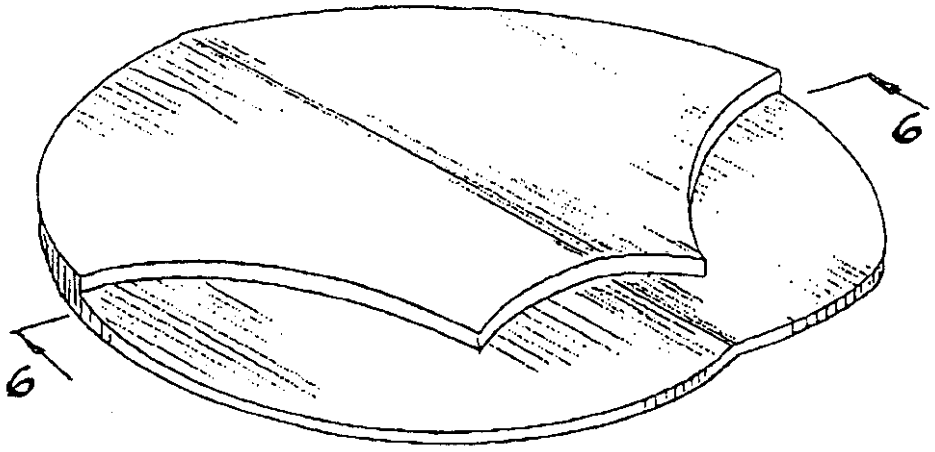

FIG. 5

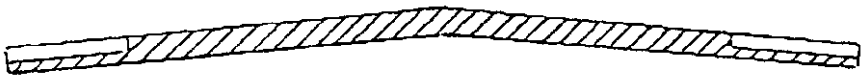

FIG. 6

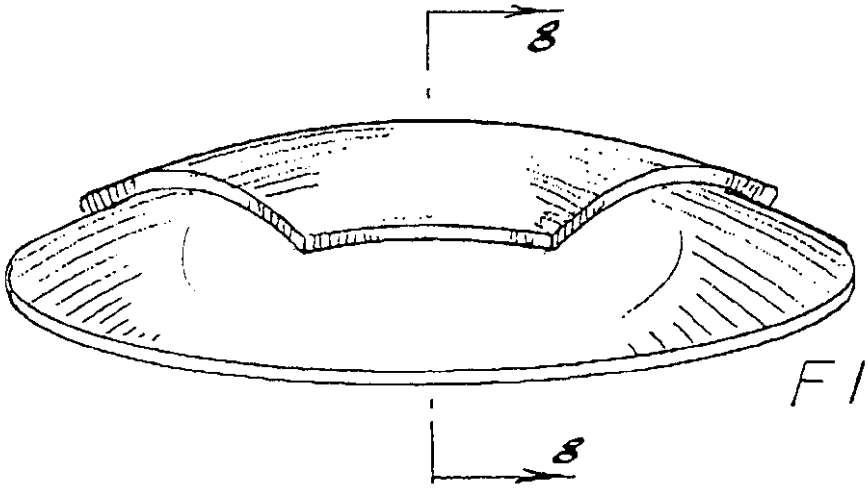

FIG. 7

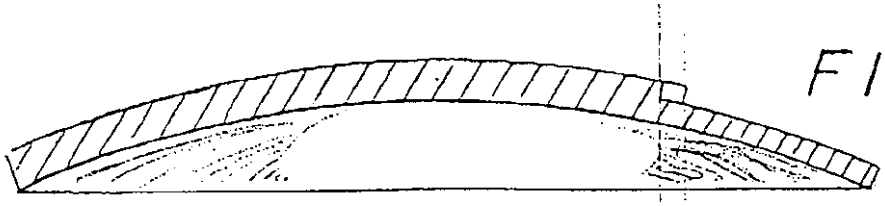

FIG. 8

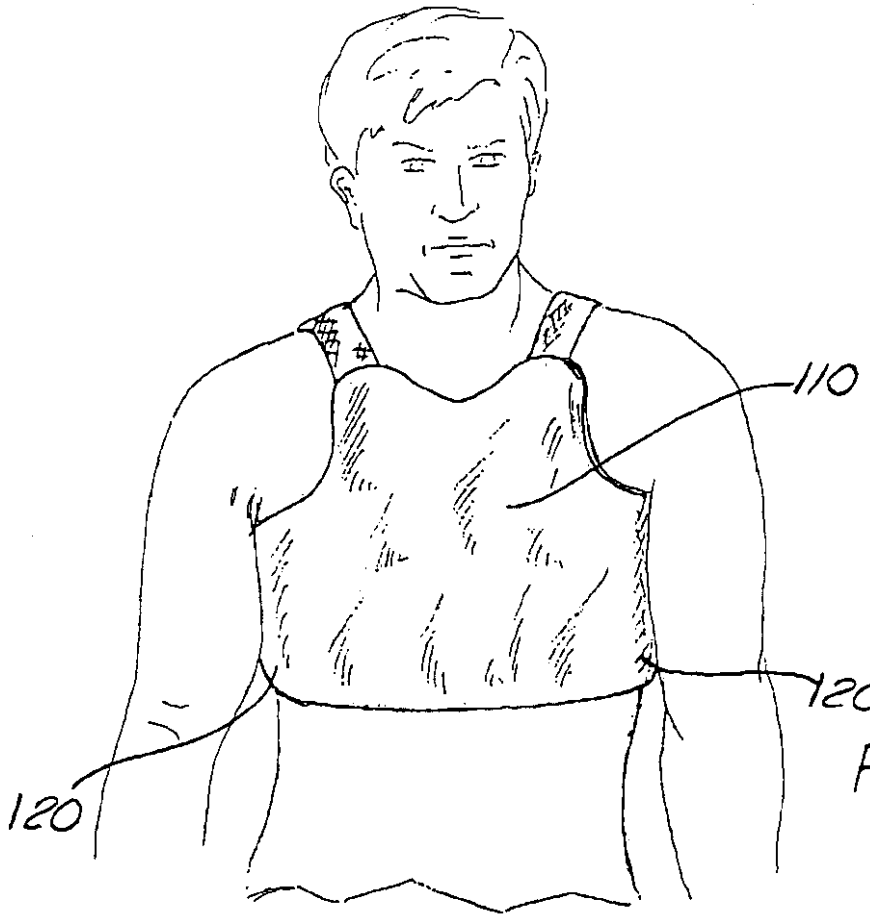

FIG. 9

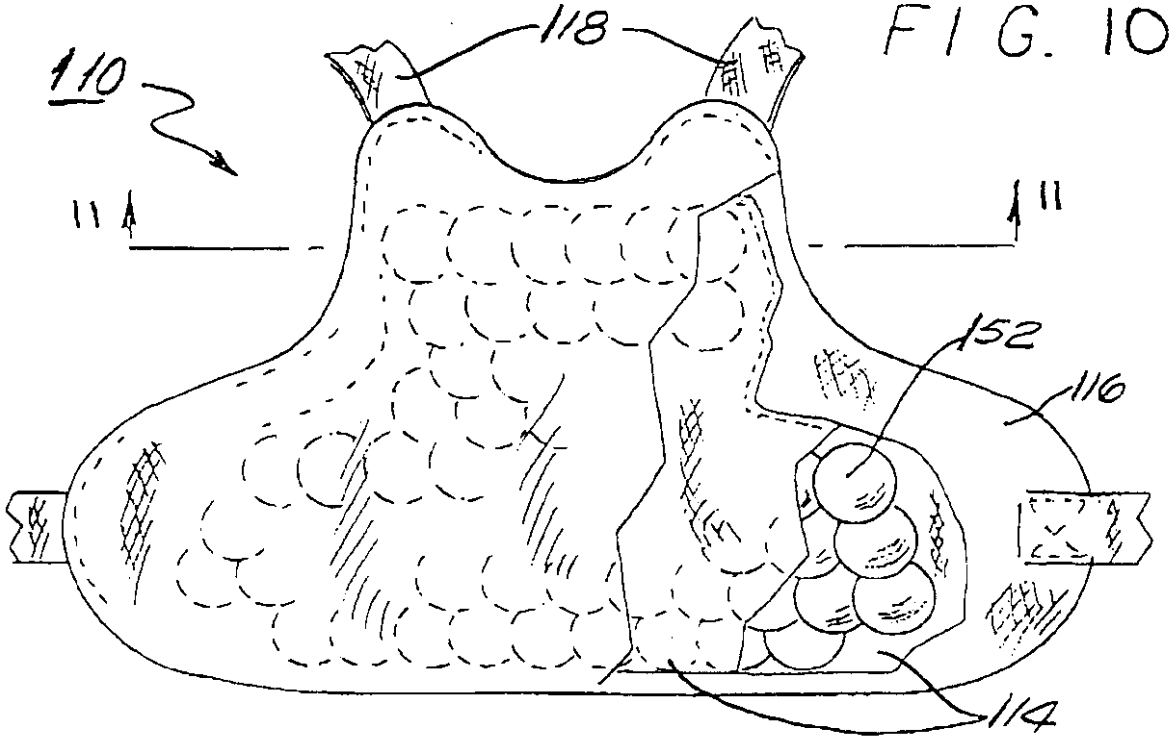

FIG. 10

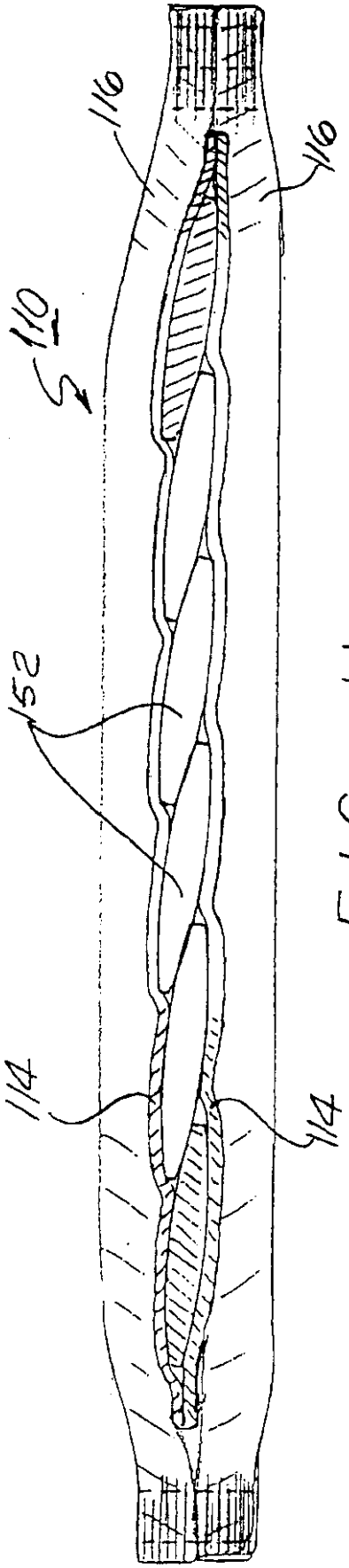

FIG. 11

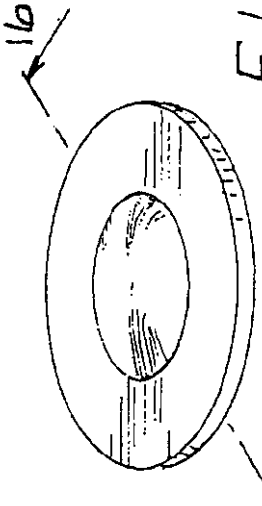

FIG 15



FIG. 16

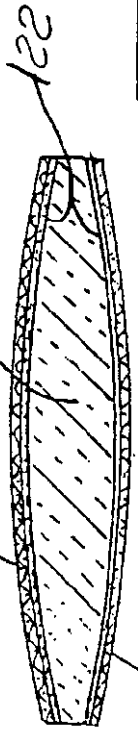

FIG 14

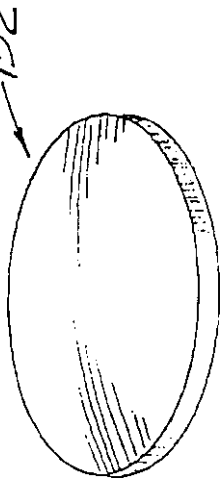

FIG. 12

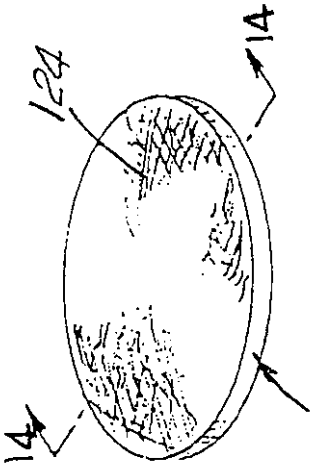

FIG. 13

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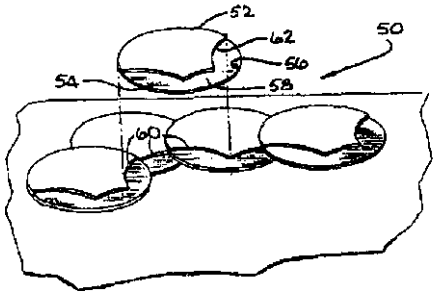
权利要求书4页 说明书12页 附图页数5页

[54]发明名称 抵挡高速射弹的方法和装备

[57]摘要

一种抵挡高速射弹的方法和装备。一些尺寸相同且厚度大于0.100"的圆盘在多个位置受到碾磨。每个碾磨位置的曲率半径大致等于圆盘的曲率半径。接着将圆盘按照鳞状结构一排接一排地进行排列,使得每排中的每一个圆盘都与该排中的其它圆盘成一条直线并覆盖住其所在一排之上的一排中的一块圆盘的碾磨位置,并使其碾磨位置被其所在排下一排中的圆盘所覆盖。然后,这种鳞状结构被粘贴到一种挠性的高抗拉强度的衬底上,并被覆盖上一层高抗拉强度层状物,使得这种鳞状结构被封装在衬底和第二层状物之间。接着将封装体连接到一种柔软的防弹衣背衬上。在另一中替代实施例中,也提出了一种抵挡高速射弹的方法和装备。制备了一由纤维诱导陶瓷复合材料构成的尺寸相同的圆盘。将这些圆盘按照鳞状结构一排接一排地进行排列,使得一排中每块圆盘都与该排中的其它圆盘基本上成一条直线,并部分重叠住相邻一排中的一块圆盘。接着,鳞状结构被粘贴到一种挠性的高抗拉强度的衬底上并被第二层高抗拉强度的层状物所覆盖,从而鳞状结构被封装在衬底和第二层状物之间。然后将该封装体连接到柔软的防弹衣的背衬上。



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权　利　要　求　书

1. 一种抵挡高速射弹的防弹衣的制造方法，该方法包括：

预备一块高硬度的板材；

切割出具有一定半径的圆盘；以及

对圆盘在多个位置上进行碾磨，每个碾磨位置的曲率半径都等于圆盘的曲率半径.

2. 如权利要求1所述的方法，其中所述板材的布氏硬度约大于450，且圆盘的半径范围在约1/2''到约2''的范围内.

3. 如权利要求1所述的方法，其还包括：

多次重复进行切割和碾磨，以生产出大量的碾磨圆盘；

将这些碾磨圆盘按鳞状结构进行排列；以及

将一高抗拉强度的衬底粘贴到鳞状结构第一侧面上.

4. 如权利要求3所述的方法，其中在该鳞状结构中，这些圆盘中的第一圆盘被其中的另外三个圆盘所部分重叠，每一个圆盘的碾磨位置都基本上完全被叠加圆盘的厚度完整的部分所覆盖.

5. 如权利要求2所述的方法，其中所述板材的厚度范围大约为0.100''到0.187''.

6. 如权利要求3所述的方法，其还包括：

将所述鳞状结构封装在所述衬底和第二层由柔韧的高抗拉强度材料构成的衬底之间；以及

将所述衬底和鳞状结构连接到柔软的防弹衣的背面.

7. 如权利要求1所述的方法还包括：

将圆盘沿某一碾磨位置的碾磨圆弧的等分轴线弯曲.

8. 如权利要求1所述的方法，其还包括：

对圆盘进行加压使之向着具有碾磨位置的表面方向凸出.

9. 如权利要求3所述的方法，其中布置方式还包括：

将所有圆盘中的一组参照第一方向排成基本笔直一排，每一圆盘都有些旋转，使得等分中心碾磨位置的轴线与该排的中心轴线的夹角不是90度，以及

参照第一方向排列随后的部分重叠排.

10. 一种装备，包括：

由具有一定硬度的材料构成的第一圆盘，该圆盘具有一定的半径和厚度，该圆盘在多个位置被碾磨，每个碾磨位置的曲率半径几乎等于该圆盘的半径，每个特定的碾磨位置都具有一从碾磨圆弧顶点到圆盘边缘的碾磨距离。

11. 如权利要求10所述的装备，其中，布氏硬度大于450，半径在0.5''到2''范围内，其所述的厚度在大约0.100''到0.187''的范围内。

12. 如权利要求10所述的装备，其中圆盘的半径大约为一英寸，且左右碾磨位置的碾磨距离大约为0.54''，中间碾磨位置的碾磨距离大约为0.50''。

13. 如权利要求10所述的装备，其还包括：

另外一些基本上和第一圆盘的尺寸一致的圆盘；以及

一种具有抗扯强度和抗切割强度的胶粘衬底，将鳞状结构排列的圆盘粘贴起来。

14. 如权利要求13所述的装备，其中，这些碾磨位置包括一右边碾磨位置、一左边碾磨位置、以及一中间碾磨位置，且其中鳞状结构是这样的，即第一圆盘的右边碾磨位置和左边碾磨位置分别被第二圆盘和第三圆盘覆盖住，第二圆盘的左边碾磨位置和第三圆盘的右边碾磨位置与第一圆盘的中间碾磨位置形成一个圆弧，第四圆盘安装在该圆弧中，从而第四圆盘将第一圆盘的中间碾磨位置、第二圆盘的右边碾磨位置、以及第三圆盘的右边碾磨位置覆盖住。

15. 如权利要求10所述的装备，其还包括：

一与衬底相连的柔软防弹衣衬背。

16. 如权利要求13所述的装备，其中，一种飞行速度为2700－2800英尺/秒，全金属甲壳为7.62×51mm，重量为150格令的射弹不会穿透柔软的防弹衣衬背，并且也不会导致大于1.73''的向后变性。

17. 如权利要求10所述的装备，其中，圆盘沿着等分一碾磨圆弧的轴线弯曲。

18. 如权利要求10所述的装备，其中，圆盘向含有碾磨位置的表面方向形成一凸面。

19. 如权利要求13所述的装备，其中，所有圆盘的第一小组被排列成第一排，该第一小组中后面的每一块圆盘都覆盖在该小组中前一

块圆盘的碾磨位置上；所有圆盘的第二小组排成第二排，使得第二排部分重叠在第一排上，第二小组中后面的每一块圆盘都覆盖在该小组的前一块圆盘的碾磨位置上，其中第一排和第二排都参照同一方向开始排列。

20. 一种装备，包括：

一种用于防弹衣中的铁饼状圆盘，其具有一定半径，与一部分半径共同延伸的第一倾斜表面，以及一定厚度。

21. 如权利要求20所述的装备，其中，该圆盘由一种陶瓷材料组成。

22. 如权利要求20所述的装备，其中，从与一部分半径共同延伸的圆盘的中心开始，圆盘的第一倾斜表面具有一基本上相同的向下倾斜度。

23. 如权利要求20所述的装备，其中，纤维诱导复合陶瓷材料含有铝，并且其硬度至少为12Gpa，其断裂韧度至少为3.8Mpa-$m^{1/2}$。

24. 如权利要求20所述的装备，其中，圆盘还包括一种纤维诱导陶瓷复合材料，该复合材料含有一种铝和韧化金属氧化物的复合材料。

25. 如权利要求24所述的装备，其中，韧化金属氧化物是一种变换韧化氧化锆。

26. 如权利要求25所述的装备，其中，变换韧化氧化锆占圆盘重量百分比约为12％。

27. 如权利要求20所述的装备，其中，该圆盘还包括一种贴在第一倾斜表面上的密封包裹材料。

28. 如权利要求27所述的装备，其中，密封包裹材料包括：

一种胶粘衬底；以及

覆盖在该胶粘衬底上的玻璃纤维材料。

29. 如权利要求27所述的装备，其中，密封包裹材料包括：

一种胶粘衬底；以及

覆盖在该胶粘衬底上的芳族聚酰胺材料。

30. 如权利要求20所述的装备，其还包括：

另外一些尺寸与第一圆盘相同的圆盘，这些圆盘按照鳞状结构布置；

一种将鳞状结构排列的圆盘粘贴起来的抗切割和抗撕扯粘性衬底。

31. 如权利要求30所述的装备，其中，鳞状排列的结构由许多排基本上排列成水平排的圆盘构成。

32. 如权利要求31所述的装备，其还包括：

连接到衬底上的柔软的防弹衣背衬。

33. 如权利要求32所述的装备，其中，该装备绕着穿着者延伸，使得由圆盘构成的鳞状结构对穿着者的防护范围超过180度。

34. 如权利要求32所述的装备，其中该装备能抵挡三级弹道危险。

35. 一种用于防弹衣中的圆盘，其具有一定的半径，与一部分半径共同延伸的一中心圆顶，以及环绕在圆顶外围的基本平坦的表面。

36. 一种抵挡高速射弹的防弹衣的制造方法，包括：

制备一些具有倾斜表面的陶瓷圆盘；

将这些圆盘在陈列表面上按鳞状结构进行排列；

将一种高抗拉强度的衬底粘贴到鳞状结构的第一侧面。

37. 如权利要求17所述的方法，其中，排列步骤包括：

将所有圆盘的一小组参照第一水平方向布置成一排基本笔直而水平的圆盘；

参照第一方向将依次部分重叠的圆盘布置成一排排基本上笔直水平的圆盘。

38. 如权利要求36所述的方法，其中，鳞状结构包括：

将每块圆盘都部分重叠在一块后续圆盘上使得每块圆盘都倾斜于陈列表面所构成的水平面。

39. 如权利要求36所述的方法，其还包括如下步骤：

将圆盘表面用一种密封包裹材料密封起来。

40. 如权利要求36所述的方法，其还包括如下步骤：

将一种玻璃纤维覆盖物粘贴到圆盘的表面上。

41. 如权利要求36所述的方法，其还包括如下步骤：

将一种芳族聚酰胺纤维覆盖物粘贴到圆盘的表面上。

说　明　书

抵挡高速射弹的方法和装备

发明领域

本发明涉及一种防护衣．更具体地说，本发明涉及一种柔韧的人体防弹衣，用于抵挡高速射弹．

发明背景

在防弹衣方面的各种进展通常与制造防弹衣的材料改进有关．近几年来，由高抗拉强度纤维构成的防弹材料，例如芳族聚酰胺纤维、聚乙烯纤维，在该领域都已被广泛地使用．遗憾的是，这些柔软的防弹衣尽管采用了这些先进的材料，却依然不足以抵挡现在被普遍使用的手枪穿甲弹、锐利的发射武器（sharp thrusting implement），以及圆形穿透器（circular penetrator）．

为了解决这种问题，已经开发出了各种坚硬的金属片装置．这种装置采用若干直径为一英寸厚度为0.32-0.50英寸的钛圆盘，这些圆盘成排地叠放，使得在一排内部，一块圆盘部分重叠在该排内的前一块圆盘上，而它又被该排内的后一块圆盘部分重叠．随后的各排圆盘部分重叠在其前一排上，而它们又被其后一排部分重叠．然后，将布置好的硬币粘贴到一种衬底，如浸透了粘合剂的芳族聚酰胺纤维上．可以用第二层浸透了粘合剂的芳族聚酰胺纤维将这些硬币构成的“板”封装起来．这种封装好的板能够粘贴到覆盖重要器官的传统挠性防弹衣上．这种防弹衣既具有较好的挠性，又薄的足以隐藏起来．

尽管硬币（coin）的这种叠置已经显示出能有效地分散冲击力以抵挡大多数现有的手枪穿甲弹、锐利的发射武器以及圆形穿透器，遗憾的是步枪子弹的连发射击就会象热刀切黄油一样穿过这种板状结构以及其下的挠性防弹衣．因此，为了抵挡步枪射击，使用者已被迫使用较大的刚性板来遮蔽重要器官．而这些较大的板比较重且没有挠性，并且使用起来通常不舒适．而且，它们几乎不可能以隐蔽的方式使用．各种试图使用具有较厚圆盘的硬币结构来生产一种商业上可行的产品以抵挡步枪射击的努力都以失败而告终．较厚的圆盘导致挠性下降且不易排列．其结果是板状结构比上述的固体板更厚，更没

有挠性，并且更重．在涉及到人体防护产品时，穿着者的舒适度也是一种额外的考虑情况．因此，这些限制使得这种结构作为一种商业产品变得不实际．

鉴于上述原因，就需要有一种能够抵挡诸如步枪射击这种高速射弹的挠性防护装置．

发明简述

一种用于抵挡高速射弹的方法和装备将被公开．对一些尺寸相同且厚度大于0.100''的圆盘在多个位置进行碾磨．每个碾磨位置的曲率半径都大致等于圆盘的曲率半径．接着，将这些圆盘按照鳞状结构一排接一排地布置，使得一排中的每一块圆盘都与该排中的其它圆盘基本上位于一条直线上，且该圆盘部分重叠在其所在排之上的一排内的一块圆盘的一碾磨位置，而其自身的碾磨位置又被其所在排之下的一排中一块圆盘所部分重叠．接着，这种鳞状结构被粘贴到一挠性的高抗拉强度衬底上，并被另一层高抗拉强度层所覆盖，结果，这种鳞状结构被封装在衬底和第二层之间．接着，封装体连接到软防弹衣的背衬上．

在另一实施方式中，公开了一种用于抵挡高速射弹的方法和装备．提供一组由纤维诱导陶瓷复合材料构成的尺寸相同的圆盘．圆盘按照鳞状结构一排接一排地布置，这样，使得一排内的每块圆盘都与该排中的其它圆盘基本上成一条直线并覆盖相邻一排中的一圆盘的一部分．接着，将这种鳞状结构粘贴到一挠性的高抗拉强度衬底上并覆以另一高抗拉强度层，使得这种鳞状结构被封装在衬底和第二层之间．接着，封装体连接到软防弹衣的背衬上．

附图简介

图1是本发明的一件防弹衣的实施例的局部简图；

图2是在本发明的一个实施例中圆盘的排列方案的透视图；

图3是一种粘贴到衬底上的鳞状结构的示意图；

图4是将鳞状结构包封在一块衬底和另外一层之间的示意图；

图5是本发明的圆盘的另一个实施例的透视图；

图6是图5所示圆盘实施例的剖视图；

图7是本发明第二个替代圆盘实施例的透视图；

图8是图7所示圆盘实施例的剖视图；

图9是一件防弹衣实施例的正视图；

图10是一件防弹衣实施例的局部视图；

图11是一件防弹衣实施例的侧向局部剖视图；

图12是一圆盘实施例的透视图；

图13是图4所示圆盘实施例带有变性环氧树脂和Eglass涂层的透视图；

图14是图5所示圆盘实施例的剖视图，图中释出了涂层；

图15是本发明一圆盘的实施例透视图；

图16是一实施例的剖视图.

发明详述

图1 是本发明的一件防弹衣实施例的局部简图. 防弹衣10覆盖在一使用者的躯干上并用于保护重要器官免受到高速射弹的攻击. 通过将圆盘以鳞状结构进行适当的排列，整个防弹衣10都保持一种挠性并且也可以针对高速射弹提供一种较好的防护. 与现有技术中的10×12的刚性板不同，这种鳞状结构能够根据身体的轮廓而弯曲并因此而相当地舒适也更易于隐藏. 鳞状结构12通常夹在两层由高抗拉强度纤维如芳族聚酰胺、聚乙烯纤维制成的织物14之间. 织物14应具有抗扯强度和抗切割强度，并且最好是用于降低破碎的防弹材料. 织物14可以用粘合剂浸透，这样，织物上的粘合剂就会粘到组成鳞状结构12的圆盘上并将它们的相对位置固定住. 可以在该夹层上增加一层或多层附加的织物14. 这将会在下面进行进一步的讨论.

位于夹在两层或多层抗扯和抗切割织物层14之间的鳞状结构12之下的是传统的柔软的防弹衣16. 如果高速射弹没有穿透底层的柔软防弹衣或没有使得向后的变形超过1.73''，该变形度是由国家司法学会（NIJ）规定的，即使高速射弹穿透了由鳞状结构构成的板也算其被抵挡住了. 象带子18这样的搭接带将防弹衣10的前面和后面以标准方式连接起来. 连接带18可以是工业上通用的任何传统带子.

图2是在本发明的一个实施例中圆盘的编排的透视图. 在这种情况下，这些圆盘是从左向右排列. 随后每排也是从左向右排列. 现在已经发现，先从左向右，然后转换为从右向左，这种转变会使得最终的结构产生缺陷，这种有缺陷的结构经常会使得防弹失效. 图2仅仅表示出了最终鳞状结构两排的局部. 每排中的圆盘基本形成

一条直线．由于圆盘彼此部分重叠，所以每块圆盘相对于垂直于排列表面的直线有些倾斜．而且，每块圆盘可以轻微地转动，使得穿过一排中心的直线与等分中心碾磨位置的碾磨弧轴线的轴线之间不会成为直角．在一实施例中，该角度约为60度．在结构50中，将一典型的圆盘52提升到其最终位置的上方以显示出来．圆盘52通常由一种高硬度的材料构成，其布氏硬度大于450．有很多材料都很合适，包括高碳钢、不锈钢、合金钢以及各种钛合金．比较好的是一种市场上销售的商标为Mars 300™ 的材料，这种材料可以从Creusot-Loure Industries（这是法国Creusot Marrel的一家分支机构）获得．Mars 300™的布氏硬度一般为630－650．商标为Bp633™ 的材料是由Astralloy of Birmingham, Alabama出售的另一种合适材料．大部分适当的材料都是以板材方式出售．购买的Mars 300™板材的厚度约为.168''．单个的圆盘需要从这些板材上切割下来．根据所使用的材料不同，这种切割可以通过等离子切隔、激光切割、或水切割来完成．在此所使用的“切割”（当不改动时）总体上指的是生产圆盘的任何技术工艺．

在一实施例中，圆盘52是采用通常的激光技术进行激光切割出来的，以确保众多的圆盘彼此具有同一直径和光滑的边缘．也可以使用水切割的方式，但水切割的效果没有激光切割好．也可以采用等离子切割，但是在切割后需要进行去毛刺和精修等额外的步骤以获得相同的边缘光滑度．在切割之后，对每一块圆盘52进行碾磨，圆盘52要在三个位置进行碾磨——左边碾磨位置54、中间碾磨位置58、以及右边碾磨位置56．这种碾磨可以按任何顺序进行．

在一实施例中，每个碾磨位置要碾磨多遍．例如，将左边碾磨位置54磨掉最终碾磨深度的大约一半．然后在中间碾磨位置58之后的右边碾磨位置56上也进行同样一半深度的碾磨．接着，进行第二遍碾磨以使得碾磨深度接近其最终的深度．最后，进行高速磨光步骤以确保每一个碾磨位置都有一个光滑的磨光面．

通常，圆盘52的半径在1/2''和2''之间．半径越长不但会降低其挠性而且也会降低制造成本．在该较好的实施例中，采用的半径为1''．根据材料不同，可以采用的圆盘的厚度在0.080''和0.187''之间．每个碾磨位置的曲率半径几乎等于圆盘52的半径．因此，如果圆

盘52的半径为1''，每个碾磨位置，左边碾磨位置54、中间碾磨位置58、以及右边碾磨位置56的曲率半径也为1''．对于厚度在0.080''和0.187''之间圆盘，碾磨深度通常为0.040''至0.080''．

每个碾磨位置都有一“碾磨距离”．在此所用的碾磨距离为圆盘52的边缘与碾磨位置54、56、58的弧顶之间的垂直距离．在一实施例中，左右碾磨位置54、56具有相同的碾磨距离，在半径为1''的圆盘上该碾磨距离为0.540''．在半径为1''的圆盘上中间碾磨位置的碾磨距离为0.50''．当以鳞状结构进行布置时，这样布置的三个圆盘要形成一个圆弧60是很重要的，在该圆弧中可以放进另一圆盘．需要特别指出的是，置于圆弧60中的圆盘只顶靠在圆盘的碾磨边缘62并覆盖住这些圆盘的左右碾磨位置．这将依赖于碾磨的深度．在一实施例中，碾磨边缘62相对于完全垂直于碾磨表面有一点倾斜．这就会减少圆盘在防弹情况下的破裂和降低在研磨设备上的磨损．

当在一实施例中，所有的圆盘都和圆盘52相同时，这就会在端部边缘存在一些碾磨位置（即，如果是从左向右排列，则在右边缘和底部；反之，如果采用的是从右向左排列，则在左边缘和底部）．这些片状件整齐地配合在一起，且部分重叠的圆盘之间没有显著的间隙．所示形状的部分重叠已经证明能有效地将高速射弹撞击力分散到相邻的圆盘上，由此而防止穿透和向后变形．在圆盘上没被另一圆盘所覆盖的碾磨位置的边缘被视为在防弹衣所提供的“防护范围”之外．

而且，由于这种结构中的每一块圆盘都有一点倾斜，几乎不可能出现垂直撞击，并且大部分能量会以反射的方式被吸收．最终，在子弹射击情况下，圆盘材料的硬度会使得射弹的尖端变大或变钝，使其穿透能力进一步降低．需要特别指出的是，这种编排结构可以制作成各种形状，使得保护区域适于躯干或其它致命区域．

在一种替换实施例中，采用的特殊精加工的圆盘具有较少的碾磨位置，以确保所有的碾磨位置都被厚度完整的圆盘所覆盖．例如，一排底部的圆盘可以碾磨成仅仅被该底排中的一相邻的圆盘所覆盖，即，只有一个右边碾磨位置（针对以从左向右排列而言），并且由于没有其它的圆盘会覆盖在该底排圆盘上，这样就会避免在底排中有薄弱点．

图3所示的是安装在衬底80上的由圆盘52所组成的鳞状结构．如前所述，衬底80是一种浸透粘合剂的聚乙烯纤维或芳族聚酰胺纤维织物．适当的织物包括由新泽西州的AlliedSignal of Morristown出售的商标为SPECTRA®的织物，由佐治亚Akzo-Nobel of Blacklawn,出售的商标为TWARON®微纤丝织物，由荷兰的DSM所出售的商标为DYNEEMA®的SB31和SB2，由日本东京的Toyobo出售的商标为ZYLON®以及由田纳西州的E. I. Dupont de Nemours & Company of Chattanooga出售的商标为KEVLAR®或PROTERA®的PBO.本领域的普通技术人员将会想到其它适当的材料.

许多适当的衬底可以利用一种覆盖有隔离纸的侵蚀性粘合剂涂层．除了具有侵蚀性外，重要的是，这种粘合剂一旦固化就会保持柔韧性以便降低圆盘和衬底之间的在遭受子弹攻击的情况下分开的可能性．可以将衬底切割成所需的尺寸，并将隔离纸剥落下来使得粘合剂表面暴露出来．接着将圆盘直接排列到粘合剂上，粘合剂使它们相对另一个的位置固定．由于衬底是具有挠性的，且圆盘可以绕其交接处弯曲，因此，该组合单元具有柔韧性．或者，先将排列好这种结构，然后将衬底粘在其顶面.

如图4所示，下一步是将另一层涂布有粘合剂的挠性衬底置于这种手工布置的硬币的另一侧，以便将它们固定在一挠性位置上，该位置在面板弯曲时不会变化，因此，尽管每一个硬币都会摆动远离其相邻的硬币，但每一个硬币的实际位置会基本上保持在其所放置的位置．用于封装鳞状结构的第二层带有粘合剂的衬底进一步加强了其耐久性，由此降低了圆盘移动和防弹衣失效的风险.

国家司法学会（NIJ）规定了危险的各种等级．三级危险为一飞行速度为2700-2800英尺/秒，全金属弹壳为7.62×51毫米，质量为150格令的子弹．现在已经证明上述发明能够抵挡三级和三级以下的危险．可以在任一侧以任意比例采用多层的方式额外增加几层涂有粘合剂的挠性衬材（即，使得板的一侧上的衬底的层数比另一侧上的多也落在本发明的范围和构思之内，）以实现不同的性能标准．在遭受射击的情况期间，许多情况会受益于硬币能轻微地移动，而其它情况下则需要硬币尽可能保持在固定位置上.

在本发明的一个实施例中，提供一种“干燥的”高抗拉强度的挠性衬底．然后在其上涂布上一中挠性粘结剂，例如，硅橡胶树脂．接着将圆盘按如上所述的结构进行排列．然后粘结剂被固化成能挠性地固定这些圆盘的相对位置．从相对一侧用一种相似的涂层将板夹在中间．采用具有一带有粘结剂且同时外表层具有上述外皮和粘性物的层状物同样落在本发明的范围和构思之内．在此所用的“浸透粘合剂的衬底”指的是在其一侧上分布有一种粘合剂的适当的挠性高抗拉强度材料，它或者从市场上买来时在适当的位置上就有粘合剂，或者如上所述一样在买来之后涂上。

在另一个实施例中，浸透粘合剂的衬底由上述方法生产，且该（夹）层无粘合剂且仅仅沿着板的周边与底部的衬底相连．这与有粘合剂的夹心结构相比将会在某种程度上降低圆盘的牢固性．因此，当多次被击中且沿周边连接的前端薄膜主要起碎片护罩作用时，这种结构将不会幸免．

图5是本发明另一个实施例的圆盘的透视图．在该实施例中，先以普通的方式制备好一种平圆盘，接着将圆盘沿中间碾磨位置圆弧的等分轴线轻微弯曲．根据防护装置所要保护部位的尺寸和曲率的不同，这种弯曲通常偏离水平面2°－15°．该实施例在半径为2’’的大圆盘的场合用作微小曲面非常合适，使得圆盘能更好地与身体的曲线相匹配．由于大圆盘意味着降低整个装置的柔韧性，因此采用较大的圆盘是比较理想的．因此，从舒适度的角度考虑，比较理想的是使得圆盘弯曲到与身体的轮廓和动作相适应．对于半径为1’’或更小的圆盘，对之进行这种弯曲没有必要也不理想．图6是图5所示实施例中圆盘的剖视图．

图7是本发明另一个圆盘实施例的透视图．在该实施例中，以上述方式制备圆盘．在进行碾磨之后但在排列之前，采用压力使圆盘从背面形成凹面，这会使得圆盘向碾磨表面方向凸出．图8是图7所示圆盘实施例的剖视图．在该视图中，凹度清晰明显．该圆盘的结构可以改进平圆盘上的偏斜特性，并且也可以提高许多穿着者的舒适度．

图9是本发明的一个实施例中一件防弹衣在穿着状态下的正视图．防弹衣110覆盖在使用者的躯干部分并用于防止致命部位被高速射弹击中．防弹衣的侧襟120绕穿着者的身体延伸以延伸保护穿着者

的侧身。在实施例中，防弹衣包裹着穿着者的某一段身体，例如躯干部分，在封闭的周向上提供基本上相同的防弹保护。

图10是一件防弹衣的实施例的局部正视图。圆盘152以鳞状结构排列，以覆盖住穿着防弹衣的致命部位。与现有技术中10×12的刚性板不同，鳞状结构能够根据身体的轮廓而弯曲并因此而明显地更舒适也更易于隐蔽起来。每块圆盘152都是由高硬度的材料形成。在一个实施例中，每块圆盘被加工成铁饼状，在圆盘的中心处的厚度最大且通过向下设置一个或多个倾斜面段而使厚度向外部边缘逐渐减小。在某一实施例中，铁饼状圆盘的厚度是以同一的向下倾斜度从中心向外侧边缘逐渐减小。在另一个实施例中，铁饼状的圆盘具有一个内圆周，圆盘在该圆周内的厚度相等且在内圆周和圆盘的周向边缘之间的向下的倾斜度是均匀的。

通常，边缘的厚度大约为中心处厚度的一半。这样，当进行鳞状结构排列时，圆盘会展现出具有比金属板或现有的硬币结构的60％的柔韧性的摆动性能。现在存在许多这样与钢铁或其它高硬度的金属相比，其重量比较轻的适当的陶瓷材料。

本发明的一实施例中与铁饼状圆盘实质上相同的锥形结构提供了非平面的圆盘，它与完全平坦的平面相比具有一个使弹道冲击发生偏转的坡度。就这点上而言，将陶瓷复合材料烧结或模铸成相同弹道等级的铁饼状比起制成金属圆盘要容易且便宜，金属圆盘的制作或者需要车加工或者需要用刀具进行切削以生产出一种类似锥形的铁饼形状。然而，铁饼状的金属圆盘也在本发明的构思和范围之内。通过将圆盘适当地布置成鳞状结构，整个防弹衣110就保持挠性并且也能针对高速射弹提供较高的防护。

此外，相对于现有抵挡高速射弹的防护材料而言，陶瓷复合材料所具有的较轻的质量和较高的柔韧性使得穿着者能具有更大的灵活性和动作范围。例如，由具有弹道等级硬度和断裂韧度的鳞状陶瓷圆盘组成的防弹背心就可以完全包裹住穿着者的某一段身体，如躯干部分，使得圆盘的保护扩大到穿着者的周身360度。重量轻的陶瓷材料也能避免典型的现有防弹衣通常的高硬度金属硬币或板所具有的显著下沉力。这就具备了爬行或游泳用途，而在该用途领域，现有防弹衣是不适合的。

同样在该实施例中，为了布置这种鳞状结构，圆盘从左向右排列．随后的每一排也都从左向右排列．已经发现，先从左向右然后转换成从右向左，这种转变会使得最终的结构不牢固，由此而使得（防弹）失效．每一排中的圆盘形成一条基本笔直的水平线．由于圆盘部分重叠在一起，所以每块圆盘都相对于垂直于水平排列表面的直线些微有些倾斜度．在一实施例中，圆盘的这种微小的倾斜度对其倾斜的铁饼形状是一种补充，从而增加了使冲击发生偏转的可能性．

在将圆盘从左到右从上到下排列好并夹装在一对粘性薄膜之间之后，整个结构被颠倒过来以便组装到防弹衣中．现在已经发现，大多数危险都是以向下的弹道方式到达．因此，比较理想的是，每一排圆盘在防弹衣被穿上时都部分重叠在其下一排．然而，以另一中顺序排列圆盘，即，从右向左从下向上排列，也在本发明的范围和构思之内．同样可以联想到在组装防弹衣的过程中将鳞状结构颠倒过来，从而使得每一排都部分重叠在其上的那排上．

现在已经发现了许多适于用作圆盘的高硬度材料的可能的陶瓷复合材料．这些材料包括由英格兰Bedforshire的Morgan Matroc, Ltd.出售的商标为SINTOX®FA和DERANOX®的陶瓷制品．特别是SINTOX®FA氧化铝陶瓷和DURANOX®的D995L，作为一种氧化锆韧化氧化铝陶瓷复合材料，由大约88%的重量百分比的铝加上21％的重量百分比的变换韧化氧化锆（TTZ）构成，它已经被证明是适当的陶瓷复合材料．

尽管铝基复合材料比较好，但其它基础材料也可以用来构成陶瓷复合材料，包括钛酸钡、钛酸锶、锆酸钙、锆酸镁、碳化硅（金刚砂）以及碳化硼．需要指出的是，这些潜在的陶瓷基材并不限定于氧化性陶瓷材料，也包括混合氧化材料、非氧化材料、象MICATHERM®（这是英格兰Bedforshire的Morgan Matroc, Ltd.出售的无机热塑性材料的商标）陶瓷一样的硅酸盐．

适当的陶瓷复合材料应具有比较高的硬度和断裂韧性．通常，这种材料所具有的硬度至少为12Gpa，断裂韧度至少为3.5Mpa m1/2以便使得防护装置能够抵挡国家司法学会（NIJ）所规定的三级射击情况．三级危险为一飞行速度为2700-2800英尺/秒，全金属弹壳为7.62×51毫米，质量为150格令的子弹．归根到底，硬度以及断裂韧度的等级

要依赖于所采用的陶瓷复合材料的种类．对于本发明采用的铝基的示例性实施例，铝的断裂韧度最小为3.8 Mpa $m^{1/2}$而氧化锆韧化铝的为4.5Mpa $m^{1/2}$．铝的硬度大约在12到15Gpa范围之内，并且对于氧化锆韧化铝而言，其硬度大约至少为15Gpa．

在某种情况下，所使用的陶瓷可以补充一种韧化剂添加剂，如韧化金属氧化物．在一实施例中，TTZ常被加进铝质基材中．掺杂进金属氧化物后会增强所得到的陶瓷复合材料的强度并阻止圆盘在弹道情况下由于冲击而分裂．对于铝质基材陶瓷复合材料，对于适当的射击等级陶瓷其中的TTZ的重量百分比的范围为0.05%到20%之间．在一实施例中，TTZ相对于铝质基材的重量百分比大约为复合材料的12%．

陶瓷可以采用现有技术中公知的方式进行配制．烧结和模铸，包括注塑，形成圆盘的方法是本领域众所周知的．在一实施例中，圆盘可以通过注塑的方式形成，然后加压成所需的形状．一旦加工成形，接着将一定圆盘实施例用一种密封包裹材料包封起来．这种材料能为圆盘提供较高的整体性，并增强其断裂韧度，因此而加强圆盘对射击子弹的冲击力的吸收能力而不会破裂．在一实施例中，这种包裹材料是一种用粘合剂基质粘附的玻璃丝纤维包裹材料．合适的玻璃丝纤维材料包括可从伊利诺斯州Summit的Owens Corning Fiberglas Technology有限公司得到的Eglass和S-2 Glass．适当的粘合剂包括改性环氧树脂．密封包裹材料和环氧树脂可以通过热压处理的方法或本领域公知的其它方式贴到圆盘上．通过在圆盘表面上覆盖上分层或交错布置在胶粘片上的芳族聚酰胺纤维，也可以赋予其强度、粘性以及结构的整体性．

通常，圆盘152的半径在1/2''和1''之间．较长的半径不但会降低柔韧性而且也会增加制造成本．在一当前实施例中，所采用的半径尺寸为1''．每块圆盘都做成在其中心区域（在此厚度最大）和边缘（在此厚度最小）之间厚度存在变化的锥形．最大和最小厚度将根据所需抵挡的射击危险等级而所有变化．例如，为了抵挡高速来复枪的射击危险，就可以采用中心最大厚度为3/8''逐渐减小到3/20''的最小边缘厚度的圆盘．低速来复枪的危险（或高速手枪的危险）则所需

要的厚度仅仅在1/8''（最大）和1/10''（最小）之间．在一实施例中，铁饼状圆盘的中心厚度为1/4''而边缘厚度为1/8''．

现在已经发现鳞状布置结构的这种部分重叠能够有效地将高速射弹的撞击力分散到相邻的圆盘上，由此而阻止了穿透和向后变形．而且，由于鳞状结构中的每块部分重叠圆盘都有一点倾斜，垂直撞击极不可能，且大部分能量以偏转的方式被吸收．在这种铁饼状实施方式中，厚度呈锥形变化，形成了一种非平面的倾斜表面，这种倾斜表面极不可能出现垂直撞击．

图11是一个由许多圆盘152构成的安装在衬底上的鳞状结构的透视图．如前所述，衬底可以是一种浸透了粘合剂的聚乙烯或芳族聚酰胺织物．上述论及的相同的织物适于与陶瓷圆盘一起使用．在胶粘衬底上的排列方式也是相类似的．

图12 是一块圆盘的透视图．在该实施例中，圆盘是一种厚度有变化的铁饼形状，其中心厚度为1/4''，并以同一倾斜度逐渐减小到周围边缘的厚度1/8''．在一种鳞状结构中，相邻圆盘的边缘相互部分重叠，形成一些具有多层圆盘的厚度较大的区域．通常这种结构不会盖住圆盘的中心或最厚的区域．因此，撞击在鳞状结构的任何一点上的射弹要么撞击在一单一圆盘上靠近最厚区域处，要么撞在厚度至少和单一圆盘的最厚的区域一样厚以及可能还要厚的多层圆盘上．而且，在厚度变化的区域之间的铁饼形状的倾斜度会弱化任何垂直弹道冲击的冲击力．

图13所示的是圆盘在使用了密封包裹材料后的透视图．如上所提到的，这种包裹材料为粘附在基片上的玻璃纤维或芳族聚酰胺纤维复合材料，该基片为一种变性环氧树脂．这种包裹材料能够使断裂韧度和硬度更高，提高圆盘在弹道射击情况下的抗破碎和分裂能力．

图14所示的是一块圆盘的剖视图，图释出了其铁饼状形状．如上所述的粘合剂层122和密封包裹层124也清晰可见．

图15是本发明另一个圆盘的实施例透视图．在该实施例中，圆盘的形状基本上和上面所述的一样．仅仅在最末部分的倾斜度有所变化．当从中心向边缘改变厚度时，逐渐变薄的坡度并不是均匀的，形成一个具有圆顶形状的中心明显凸出的部分．这就使得从外周边缘到到圆顶中心之间延伸的表面区域基本上是平坦的．该实施例使得圆盘

进行部分重叠的表面面积变大了，也增加了射弹着落在多层圆盘上的表面面积．然而，大致平坦的区域也增大了垂直撞击的可能性．这种圆顶状的圆盘也能以与上述方式相似的方式进行排列，并组装在能够抵挡三级危险的防弹衣中．

图16是图6中所示的另一个实施例的侧视图．

在前面的说明中，已经参照本发明的具体的实施例对其进行的描述．然而，需要指出的是，在不脱离如后面所附的权利要求书所提出的本发明较宽的构思和范围的情况下，是可以作出其它的各种修改和变化．因此，该说明书和附图应被认为是说明性的而不具备限制意义．因此，本发明的保护范围应该也仅仅由附后的权利要求书来限定．

说 明 书 附 图

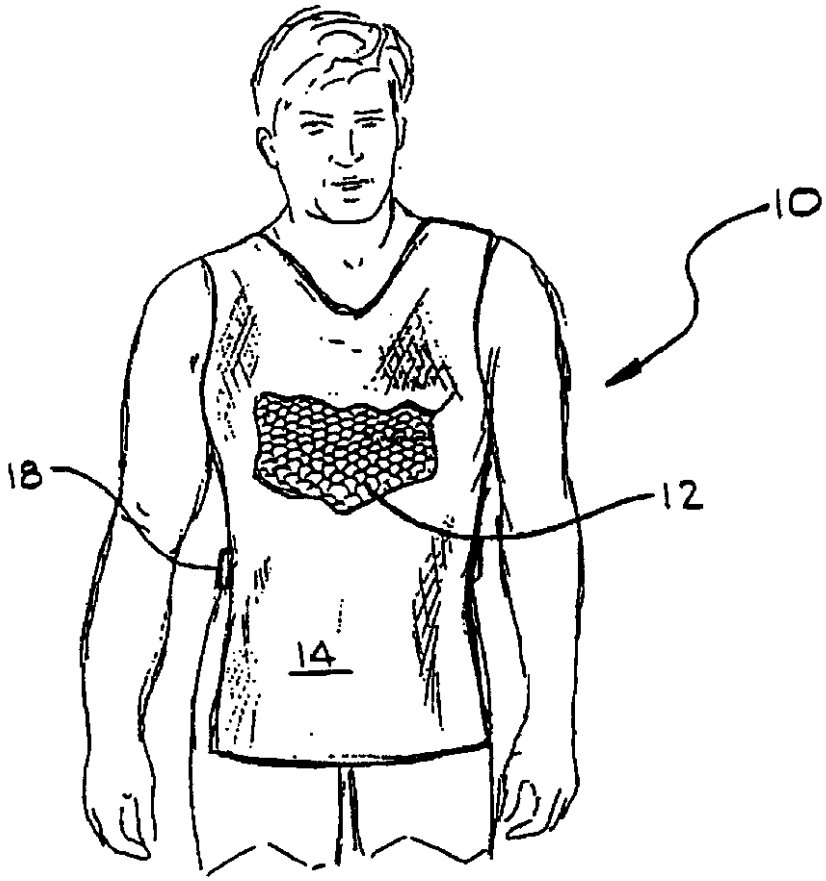

图 1

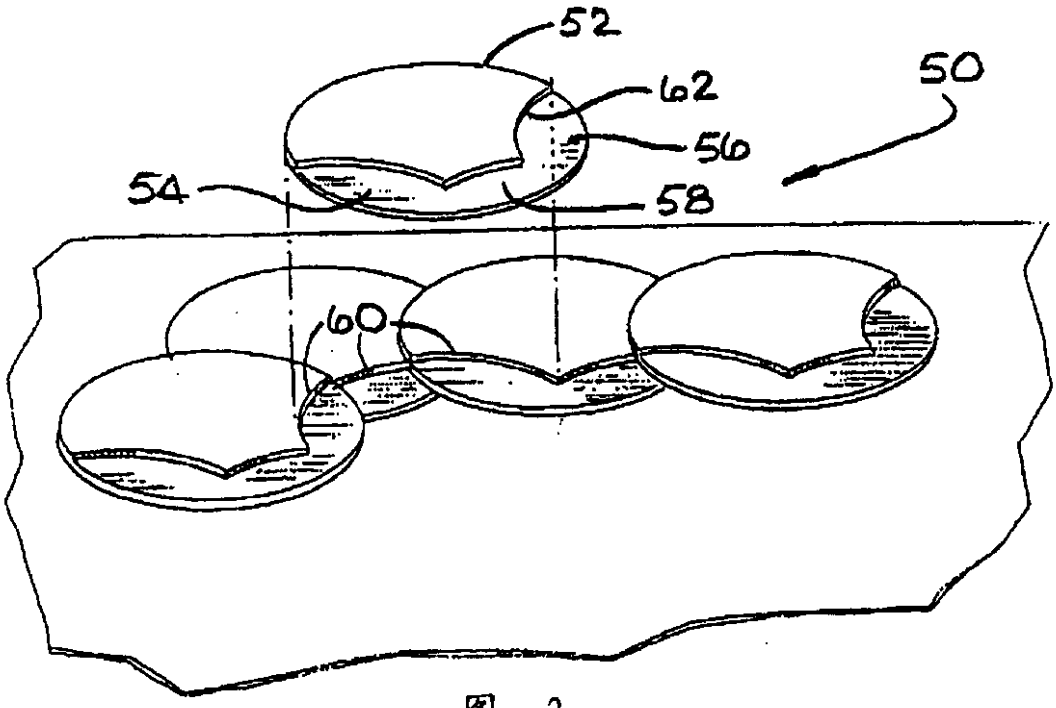

图 2

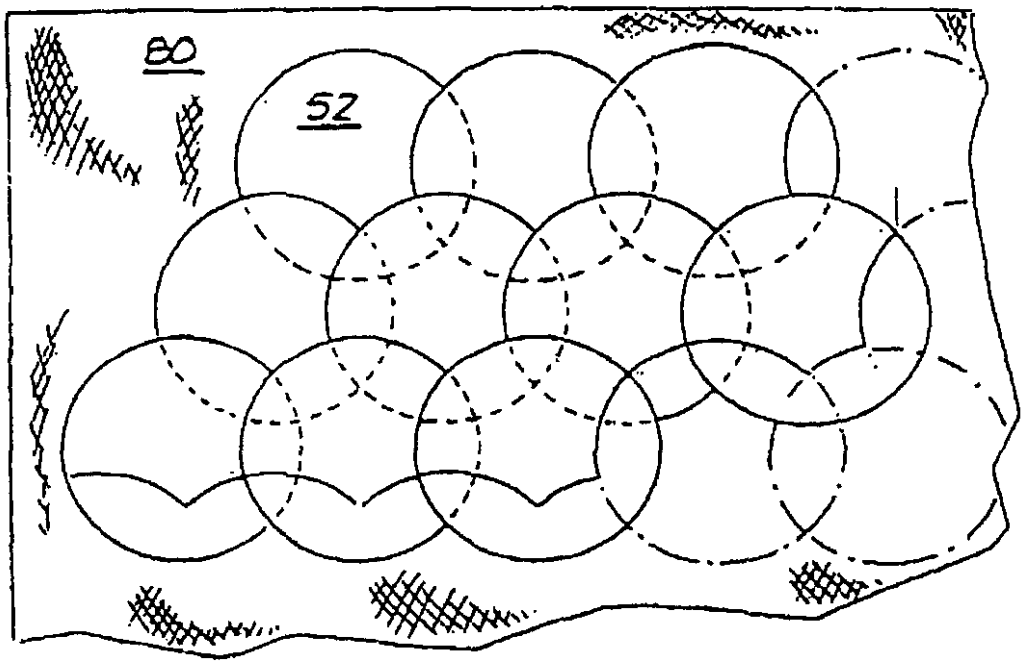

图 3

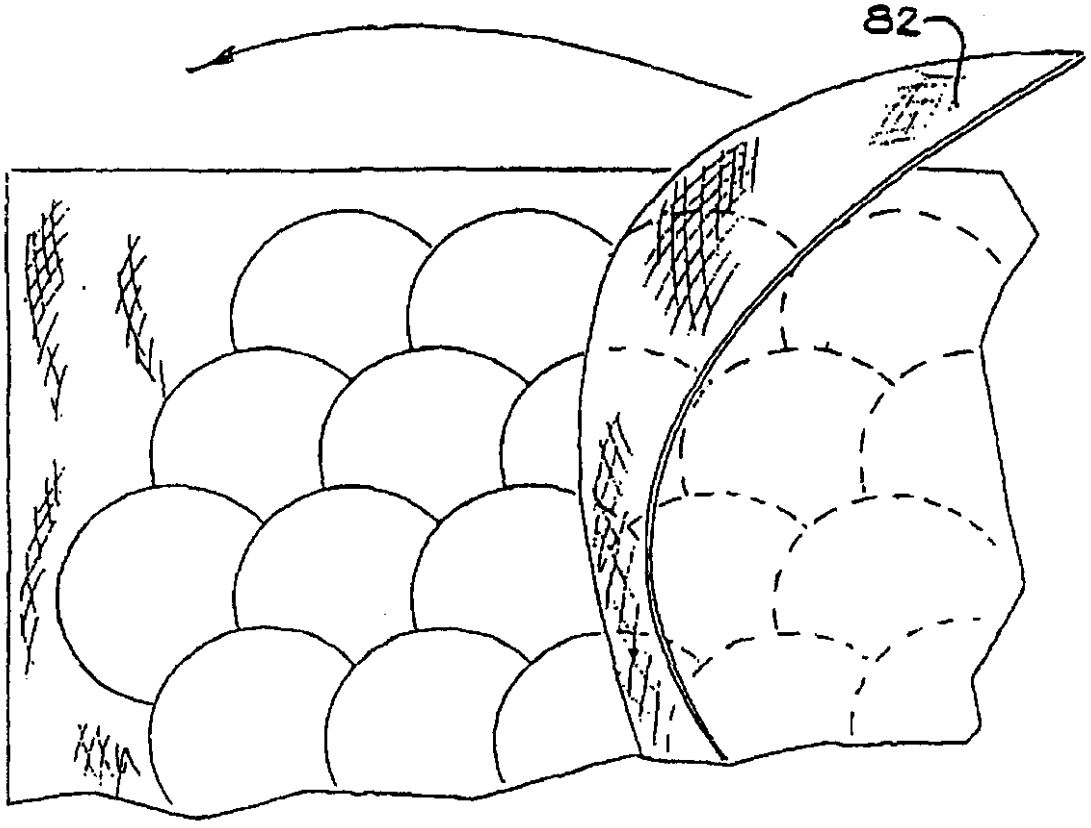

图 4

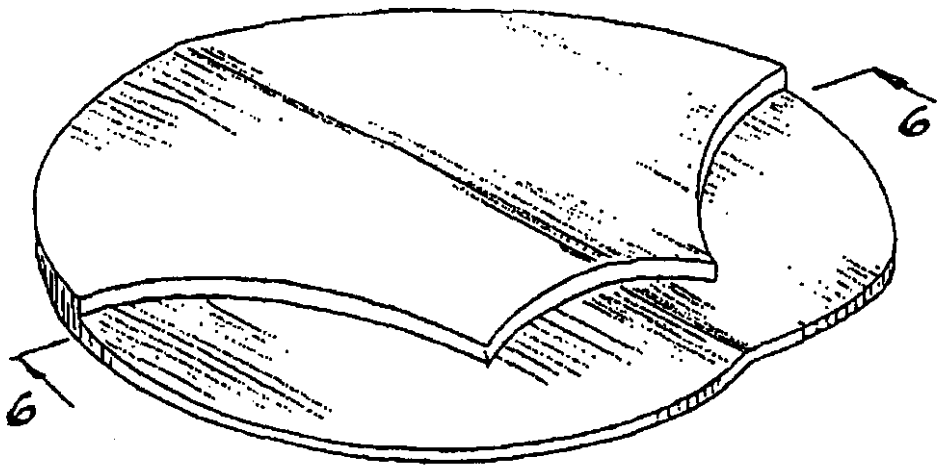

图 5



图 6

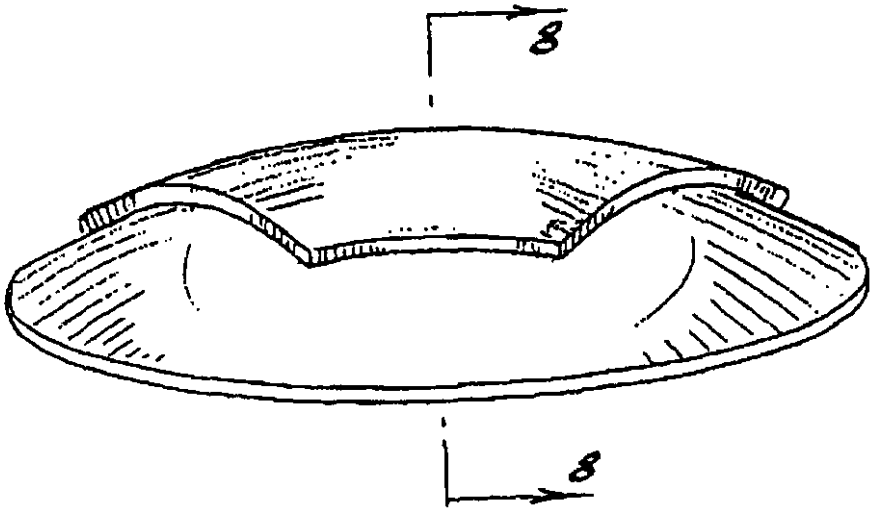

图 7

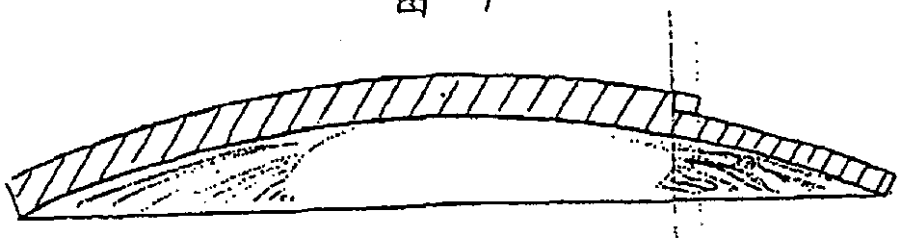

图 8

01.06.28

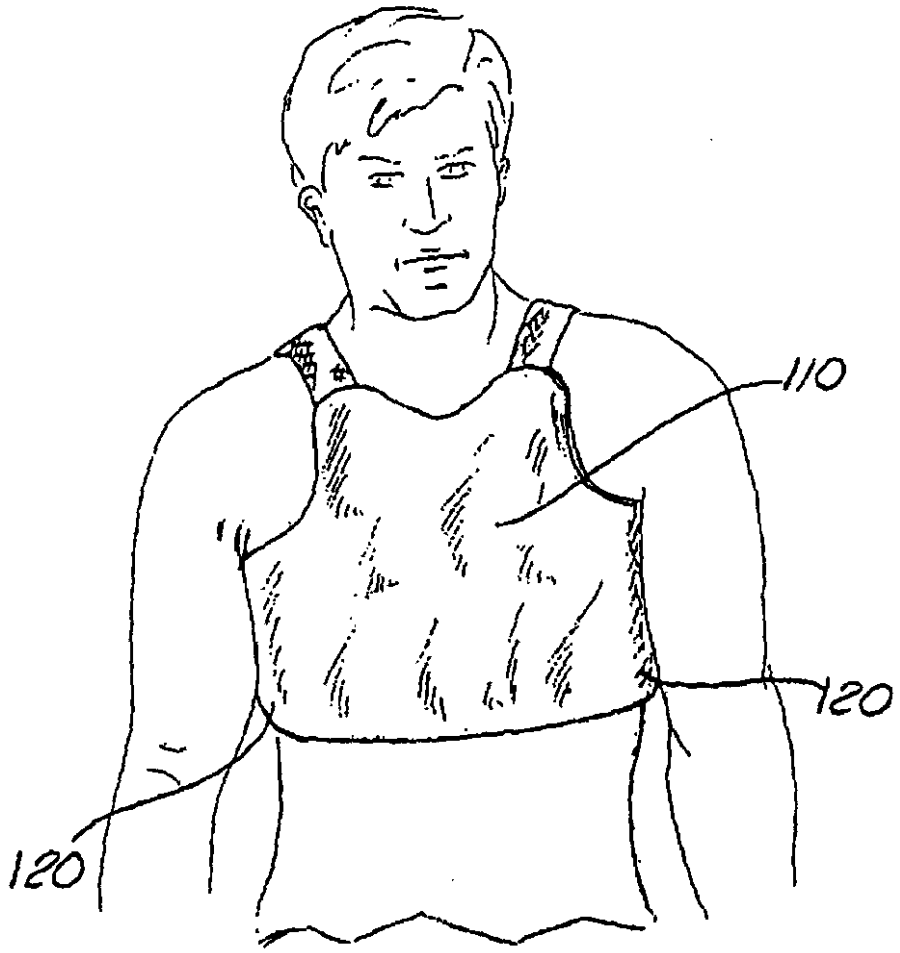

图 9

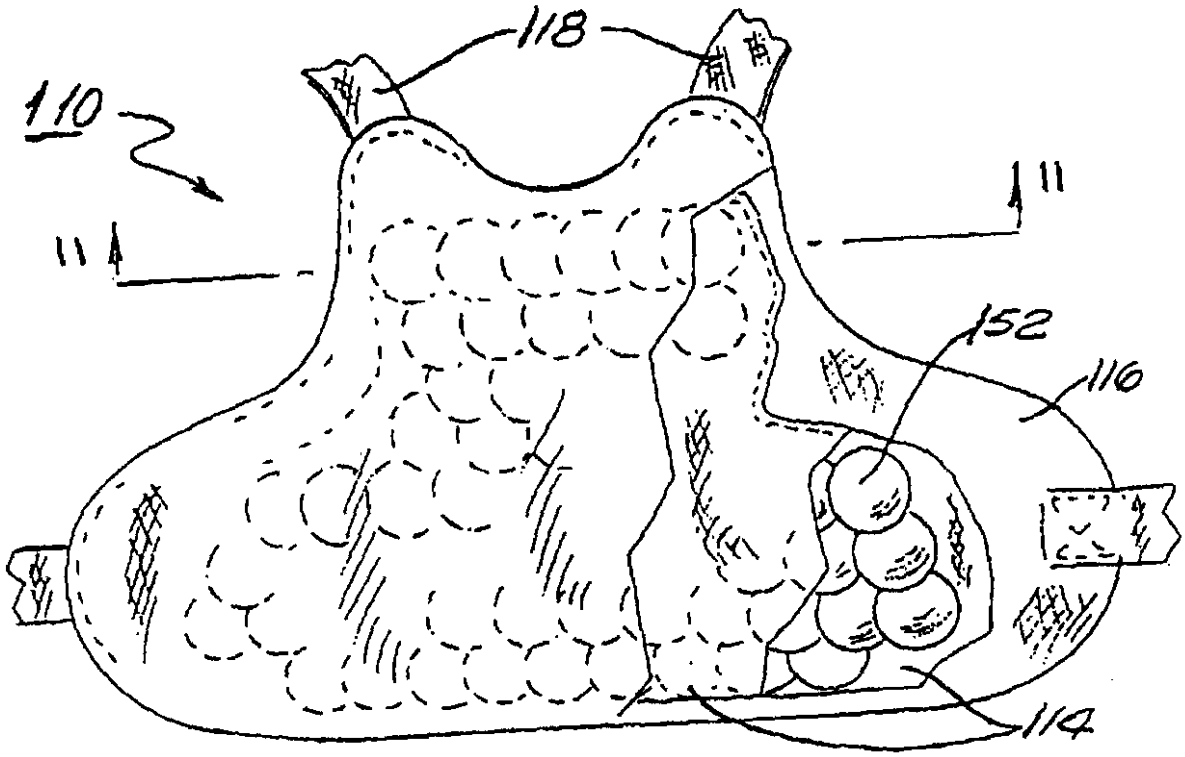

图 10

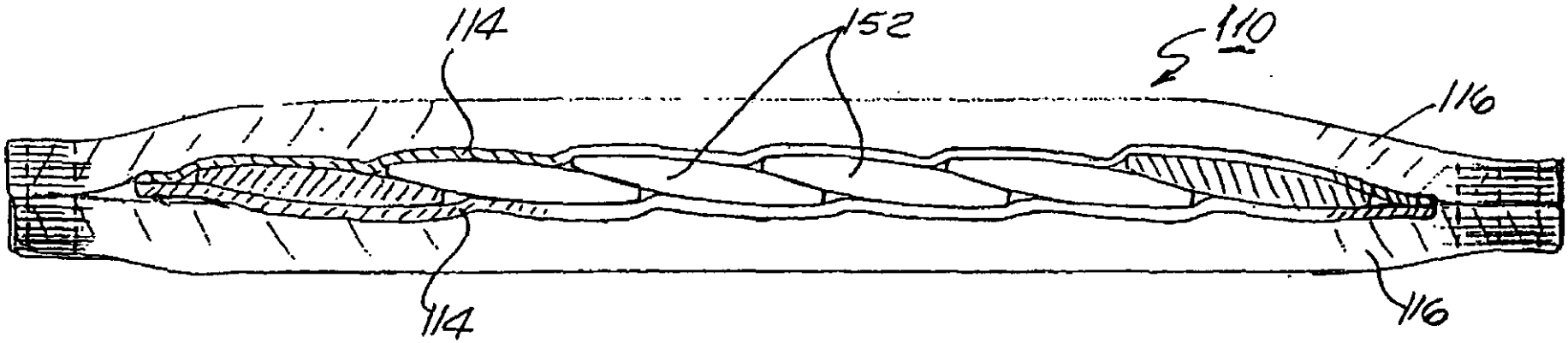

图 11

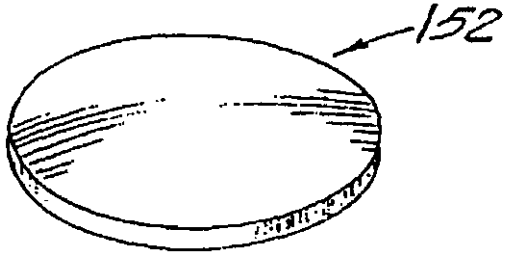

图 12

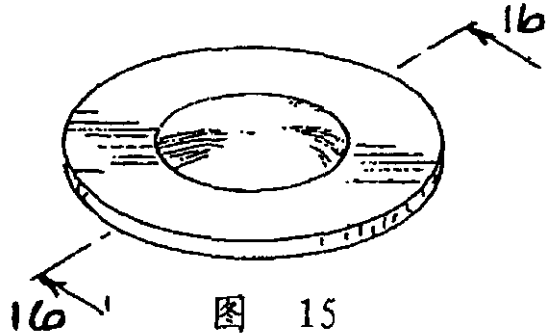

图 15

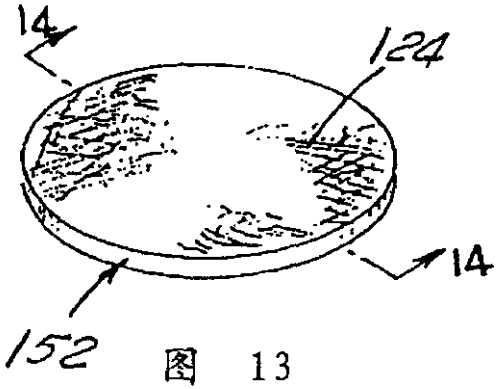

图 13

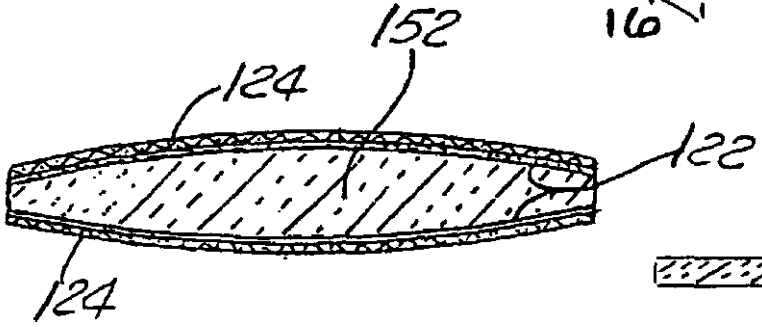

图 14



图 16