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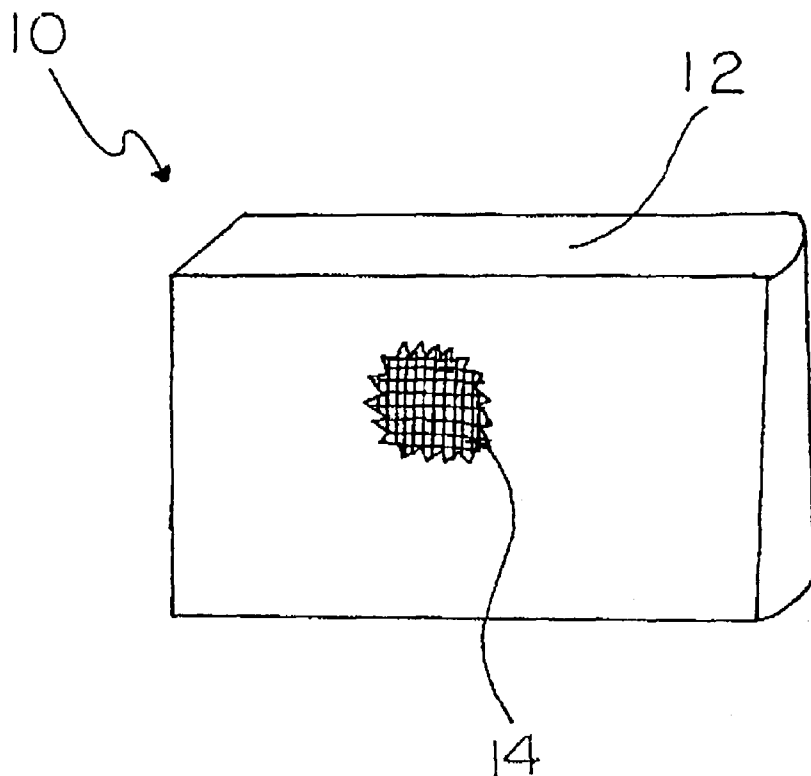


FIG. 1

(57) Abstract: A new plastic encased anti-ballistic material, one which may be tailored for multi-threat protection. Also disclosed is a method for forming such a new anti-ballistic material or article by describing a method of forming plastic particulates into a multiple skin configuration, usually two skins, which may also have contained therebetween either an expandable plastic material, along with the anti-ballistic material reinforcement for strengthening the plastic article, other filler materials, or combinations thereof. In addition to the materials which can be incorporated into the middle layer between two skins, the present invention also discloses the use of multiple layers of various types of anti-ballistic materials to combat any type of ballistic threat which may happen.

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# **PLASTIC ENCASED MULTI-THREAT ANTI-BALLISTIC MATERIAL**

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## **TECHNICAL FIELD**

This invention relates to an encased anti-ballistic material panel and/or component, and more particularly relates to a securement and encasement method and material for enclosing an anti-ballistic material to hold it in place.

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## **BACKGROUND OF THE INVENTION**

Anti-ballistic materials have been known in the art for a long time, although there has always been a difficulty with placing the anti-ballistic material into position as to be most effective.

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The most conventional anti-ballistic material has been plate steel. Plate steel effectively has prevented bullet penetration, although its extreme weight has limited its use to buildings and vehicles as the steel plate was too weighty for personal body armor. Still, steel-plated vehicles or steel-lined vehicle compartments reduce fuel economy so greatly that another solution has been sought. Engineers have been looking for a lightweight anti-ballistic material that will stop high velocity bullets.

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Previously, some scientists have proposed the use of epoxy resin to hold Kevlar®, available from DuPont Corporation of Wilmington, Delaware, USA, and/or Dyneema®, available from DM Dyneema B.V., of the Netherlands, respectively, disclosed further hereinbelow, in order to maintain the position of the anti-ballistic material. The anti-ballistic material has conventionally been formed into sheets or panels, and may be inserted into a pocket, for instance such as current military issue personal body armor, or it may be glued onto the outer or inner surface of a vehicle or helicopter. In other prior art attempts, aramid fibers or ceramics were pressed together using an epoxy resin to glue the pieces into a

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unitary composite structure. However, these structures have proven to be excessively heavy, difficult to incorporate into vehicles or aircraft, and are relatively ineffective in maintaining the position of the anti-ballistic material where it is needed.

5 Conventional personal body armor with anti-ballistic materials have included the use of high tensile strength fibers such as, for example, aramid fibers and polyethylene fibers. These materials have been placed into personal bulletproof vests to protect the torso of the wearer. Multiple layers of high tensile strength aramid or polyethylene fabric have been required because a single layer has proven to be insufficient to stop a ballistic projectile. Due to the multiplicity of layers, weight was a real issue. However, the multiple  
10 layer configuration has been deemed to still be advantageous because attaching enough fabric necessary to defeat a ballistic projectile has still left the vest lighter and more flexible than it would be had it been made out of metal.

Multiple layer Kevlar® vests are usually sufficient to defeat ballistic pistol rounds. One method of measuring the ability of a bulletproof vest to defeat these rounds has been  
15 established by the United States of America National Institute of Justice (NIJ). The NIJ Standard 0101.04 for Threat Level II involves testing body armor against 9 mm, 124 grain full metal jacket projectiles at 1205 feet per second, as well as against 0.357 Magnum, 158 grain semi jacketed hollow point projectile at 1430 feet per second. The NIJ Standard 1001.04 for Threat Level IIIA involves testing body armor against 9 mm SMG (sub-  
20 machine gun), 124 grain full metal jacket projectiles at 1430 feet per second (fps) and .44 Magnum, 240 grain jacketed hollow point projectiles at 1430 fps.

The highest level of protection standard the United States of America National Institute of Justice has issued for pistol rounds is the Level III-A Threat. The Level III-A threat is designed to simulate high velocity pistol rounds traveling at least 1,400 feet per  
25 second when they impact. The NIJ III-A Level Threat is part of the National Institute of Justice Standard 0101.04. Another part of the NIJ Standard 0101.04 is a standard for backface deformation allowed by the vest. As part of this backface deformation standard, a vest, even when it stopped a ballistic projectile completely, is allowed to deform towards the body no more than 44 millimeters (mm), or 1.73 inches (in) as measured into a  
30 standard clay material.

The damage done by ricochet fragmentation can be modeled using a bullet type sabot fragment simulator, such as a right round circular penetrator with blunt ends about 0.217 inches in diameter and 0.220 inches in length. Another simulator for fragmentation protection is defined by United States of America Military Standard (Mil Std) 662E. Military Standard 662E calls out a 16 grain chisel point, right round circular penetrator that impacts the vest at a velocity of at least 650 meters per second (mps) (2132 feet per second).

Threats faced by military personnel are usually bullets and/or fragments or shrapnel. Military pistol ballistic projectiles usually include a military 9 mm ball round. Fragmentation or shrapnel projectiles are typically generated by the destruction of a casing of an explosive round. The explosive round can be either artillery, mortar or grenade.

Kevlar and other aramid fabrics have high resistance to penetration by ballistic projectiles. This resistance to penetration comes from a combination of the fiber tensile strength, elongation of yield, selected pick count, and high heat resistance of the aramid fabric.

High tensile strength fibers in an aramid fabric with a high elongation of yield have an ability to deform and slow down a ballistic projectile. A ballistic fiber with a higher elongation to failure will tend to hang on to the projectile as the fibers of the material stretch. The stretching of the material allows additional time for the fabric to hang on to the projectile deforming the projectile and slowing it down as fibers elongate, before yielding to penetration. Deforming the ballistic projectile causes the front end of the projectile to expand radially normal to the direction of its flight in a manner that can be described as mushrooming. This action is described as mushrooming because the stopped bullet, when removed from the vest, tends to look like a mushroom. Causing the leading surface of a projectile to expand is advantageous, because an expanded leading edge has greater surface area in contact with the vest material. A ballistic resistant vest material is better able to stop a projectile with a larger surface area in contact with the vest, because that allows more threads of the fabric to engage the projectile adding their tensile strength to the stopping power of the fabric.

Pick count is a measure of the number of threads of fiber in a given area of fabric. The greater the pick count the greater the number of threads in a given area the fabric has. Each thread in the shadow of the projectile impact absorbs energy from the projectile

when it yields. Thus a fabric with a high pick count may have a greater resistance to penetration than a fabric with an identical thread but a lower pick count.

In adjusting the denier and pick count of a fabric, care must be given so as to not place too many fibers with too high a denier in a given area. As denier increases, the diameter of the fiber increases. Increasing the denier of a fiber without reducing the pick count of the fabric may lead to crimping. Crimping occurs when the fibers are so tightly packed together at crossover points that the fibers cannot elongate. When crimping occurs there is no benefit gained from the fiber's ability of the fiber to stretch. Thus, too high a denier combined with too high a pick count results in crimping and reduced anti-ballistic efficiency of the fabric.

Aramid fabrics have a high resistance to heat. Ballistic events, where a projectile is deformed and stopped, generate a significant amount of heat. Aramid fabrics retain their structural integrity in high temperature episodes better than other fabrics. This high resistance to heat allows aramid fabrics to retain their high tensile strength and elongation of yield during ballistic events. In addition, the heat generated at impact helps to soften the projectile and adds to the deformation of the projectile caused by impact with the fabric.

Polyethylene fabric is traditionally made by combining fibers and sheets of polyethylene. The fibers are coated in a resin and a unidirectional layer of fibers is cross laid with another unidirectional layer of fibers at 90° to each other. The fibers are then sandwiched between two polyethylene sheets to form a fabric. The polyethylene fabric has an enhanced ability over aramid fabric for absorbing the energy of a projectile, and by absorbing this energy, reduces the backface deformation generated by a stopped projectile. Backface deformation is a measure of how deep a projectile penetrates into the vest wearer's body. Even though the vest does not completely fail, the projectile penetrates before it is stopped. In order to meet National Institute of Justice Standard 0101.04, for backface deformation, the deformation can be no greater than 44 mm, or 1.73 inches into a standard clay modeling material.

## **SUMMARY OF THE INVENTION**

5           The present invention discloses a new material of a plastic encased anti-ballistic material, one which may be tailored for multi-threat protection. Also disclosed is a method for forming such a new material or article by describing a method of forming plastic particulates into a multiple skin configuration, usually two skins, which may also have contained therebetween either an expandable plastic material, along with the anti-ballistic  
10 material reinforcement for strengthening the plastic article, other filler materials, or combinations thereof. In addition to the materials which can be incorporated into the middle layer between two skins, the present invention also discloses the use of multiple layers of various types of anti-ballistic materials to combat any type of ballistic threat which may happen, as well as other embedded articles to be placed between the two skins,  
15 whether they are completely embedded into the article, or whether portions of them are allowed to extend therethrough outside the molded article, i.e. for purposes such as securements, or vehicle mounting brackets, electrical wires, and the like.

          The present invention holds desirable anti-ballistic materials in position for several reasons: 1. In order to hold the anti-ballistic material in place while protecting it from the  
20 outer elements; 2. To allow for multi-layers of various anti-ballistic materials to help with multi-threat situations; and 3. to be able to incorporate such materials into body or vehicle components such as the underbelly of a helicopter, the underpanel and side door panels of Humvees or Strykers or the sides of a boat for naval operations. In addition, our tests show that the anti-ballistic woven materials tend not to fray when they are held in place, or  
25 foamed in place between skins that absorb the bullet and do not allow backfire deformation.

          Any appropriate material may be utilized for the plastic encasing of the outer skins or foamed materials for encapsulating the anti-ballistic materials, including polypropylene, polyurethane, and/or other thermoplastic or "thermoset" resins. These materials, in yet  
30 another aspect of the present invention, are expected to bond nicely with foamed plastic or foamed alumina, silicon carbide or silicon nitride due to the open-celled foam concept that

may be desirable for various aspects of this invention. Foamed ceramics and metals are known in the art, and may be used in an advantage for certain applications.

One aspect of the present invention employs at least one layer of Kevlar™ KM2 600 denier fabrics, or Dyneema™ SB31 fabrics. One of ordinary skill in the art would recognize however that with adequate notice given to denier, pick count and elongation of failure, various materials might be substituted for the materials mentioned above. The threat to be protected from will dictate the material layers that will be incorporated into the plastic encasement, more fully described in detail hereinbelow.

## **BRIEF DESCRIPTION OF THE DRAWINGS**

Fig 1 is a perspective cutaway view of a panel made in accordance with the present invention;

Fig 2 is a side elevational view of a cutaway section of the panel of Fig 1;

Fig 3 is a side elevational view of a cutaway version of another embodiment of the present invention; and

Fig 4 is a side elevational view of yet another embodiment of the present invention.

## **DETAILED DESCRIPTION OF THE INVENTION**

In accordance with the present invention, there are disclosed various processes for forming encased anti-ballistic materials, especially encased in various forms of plastic, descriptions of the apparatuses which are useful for performing those processes, and certain articles made therefrom. Needless to say, the scope of the invention will be determined by the claims and shall not be otherwise limited. As with all new materials and forming technologies, the number of applications and permutations of those applications are so numerous, they cannot all be mentioned here. However, in the spirit of providing the best mode and detailed description of many of the embodiments, the following description will be broken down into paragraphs, followed by specific applications and their descriptions.

Looking first to Fig. 1, there is shown a fully encased anti-ballistic panel generally denoted by the numeral 10 including an encasement material 12, surrounding

and enclosing an anti-ballistic material 14. Anti-ballistic material 14 may be selected from the group consisting of aramid fibers, Kevlar, Dyneema, para aramids such as PBO, Zylon™, various denier Kevlar™ KM2 materials such as 500 or 400 denier material, Kevlar™ 129 500 or KMz 600, and 400 denier material, Spectra™ polyethylene fabrics, and Dyneema™ polyethylene fabrics such as their SB31, bullet-proof steel, bainite steel, boron carbide, silicon carbide, silicon nitride, alumina, or any other carbide, nitride, oxide or any other suitable ceramic material, or any version of any of these ceramics or metals. Encasement material 12 may be of any suitable material, one that will hold the anti-ballistic material in place and in position. One aspect of the invention discloses a total encasement, where the outer covering 12 may be sprayed on, dipped, plasma sprayed, powder melted, powdercoated, hard-face laminated by heat pressing, powder pressing, heat-curing foam, heat-curing gel, heat-curing aerogel, liquid and light cured gels.

Looking next to Fig. 2, there is shown a composite configuration generally denoted by the numeral 20, in which an outer skin 22 surrounds a foamed material 30 which encapsulates various anti-ballistic materials, 24, 26 and 28, respectively, in between another foamed layer 32 followed by a hard outer coating 34. The three anti-ballistic materials 24, 26 and 28 may be all the same material, such as for example three layers of multiple Kevlar or Dyneema panels, or they may be any combination of the materials listed hereinabove in the previous paragraphs. There can be any number of anti-ballistic panels, including more or less panels than just 24, 26 and 28. The number of layers needed will depend on the materials selected. Outer coverings 22 and 34 may be the same materials or they may be different materials.

Looking now to Fig. 3, there is a new anti-ballistic composite disclosed and shown which is generally denoted by the numeral 40, showing a multi-layer structure including a first and second anti-ballistic material 46 and 48, respectively adhered to a foamed material 44 and having a gel 42 on the opposite side. Again, any number of anti-ballistic materials can be stacked and/or laminated, and/or glued together to form as the center of the composite structure.

Lastly, we look at Fig. 4, wherein a multi-layer composite structure generally denoted by the numeral 50 includes a ceramic anti-ballistic material 52 sandwiched

between two foamed areas 54 and sealed by first and second outer coatings 56 and 58, respectively.

In general, one of the best modes of the present invention and process can be most basically described as the use of a set of molds which is heated and contacted with at least a polyolefinic plastic particulate material. Such a method and materials are described in United States Patent Application Serial Number 10/239,039 having a priority date of 05 FEB 2001, which is incorporated herein by reference.

In this aspect of the invention, the polyolefin material may be in the form of powder, pellets, resin, shavings, or whatever. The step of contacting accomplishes the melting of the plastic particles into a formed article against the shape of the heated mold. The mold will be most advantageously shaped to yield a structural component for military or police vehicles, boats, fixtures, personal armor vests, and the like.

A sandwich-type of composite material can be made by making both male and female mold portions, forming "skins" on each of the molds, and placing materials in between the two skins in a clamshell-type configuration with a filler or foaming plastic in between. Generally, the expandable foam is activated by the residual heat from the molds.

The thickness of the outer skin of the article is determined by the length of time the heated mold comes into contact with the plastic. For example, a heated mold elevated to a temperature of from approximately 100°C to 865°C can be placed in contact with a powdered polyethylene material and will achieve a plastic skin thickness of approximately 1mm for every minute that the mold is contacted with the plastic. For most of the applications described hereinbelow, it is most advantageous to have the plastic formed on the mold of a thickness from about 1mm thick to about 10mm thick, requiring a contact dwell time of between about 1 minute and 10 minutes. If other polyolefin materials are utilized, such as plastic pellets, which are much less expensive than ground plastic powder, the contact time must be adjusted accordingly. Specific times will be described hereinbelow with regards to specific applications and specific materials.

Furthermore, the outer skin of the article may be sprayed thereon to a desired thickness prior to the embedding of the anti-ballistic material between the two outer skins. In addition, a expandable material may be inserted into the mold and heated to expand the

expandable material to encase the anti-ballistic material between the two outer skins, as well as holding the anti-ballistic material securely in place within the foamed up expandable material.

5 A sandwich-type of composite material can be made by making both male and female mold portions, forming "skins" on each of the molds, and placing materials in between the two skins in a clamshell-type configuration with a filler or foaming plastic in between. Generally, the expandable foam is activated by the residual heat from the molds.

10 The anti-ballistic materials that would be selected for encasement in accordance with the present invention would be determined by the application that it was intended to be used for. In other words, the personal body armor that might be produced could be used for police and military, as there may be less armor piercing bullets used, while an armorment for a vehicle may want to use Dyneema and anti-cannon anti-ballistic materials such as bainite steel or titanium to resist IED blasts and land mines.

15 In various other aspects of the present invention, the foamed materials described hereinabove may be used as backface signature deformation and suppression materials in order to prevent and/or inhibit ricochet effects after a ballistic projectile has hit the anti-ballistic multi-layer unit. Therefore, a multi-threat panel or unit can be designed by incorporating into the sandwich concept of various materials, such as layering of a boron carbide panel over Dyneema panels which could be also utilized next to a bainite steel.

20 The present invention holds desirable anti-ballistic materials in position for several reasons: 1. In order to hold the anti-ballistic material in place while protecting it from the outer elements; 2. To allow for multi-layers of various anti-ballistic materials to help with multi-threat situations; and 3. to be able to incorporate such materials into body or vehicle components such as the underbelly of a helicopter, the underpanel and side door panels of Humvees or Strykers or the sides of a boat for naval operations. In addition, our tests show that the anti-ballistic woven materials tend not to fray when they are held in place, or foamed in place between skins that absorb the bullet and do not allow backfire deformation.

30 Any appropriate material may be utilized for the outer covering or foamed materials for encapsulating the anti-ballistic materials, including polypropylene, polyurethane, and/or

other thermoplastic or "thermoset" resins. These materials, in yet another aspect of the present invention, are expected to bond nicely with foamed plastic or foamed alumina, silicon carbide or silicon nitride due to the open-celled foam concept that may be desirable for various aspects of this invention. Foamed ceramics and metals are known in the art, and may be used in an advantage for certain applications.

For example, magnesium and aluminum can be foamed and used as the outer layer as is shown in Fig. 3. In addition, those materials may also be mixed with a polyurethane powder in combination with a blowing agent and the foaming action of the blowing agent with the polyurethane can infiltrate and encapsulate a foamed metal, such as the foamed aluminum, in order to add rigidity to a component while also adding anti-ballistic qualities.

The outer coating may also be a shrinkwrapped plastic or an enclosing membrane plastic, or even vacuum formed materials if the foamed metal or foamed plastic sections such as shown in Figs. 2, 3 and 4 are porous. The exterior coatings may be heat shrunk thereon, or sprayed, plasmasized, melted, dipped, or any other method for applying a carbonaceous material or other gas, liquid or solid in order to form a hard shell on the outside after it has been dried, cured or whatever else in order to make it hard.

Known anti-ballistic materials are disclosed in the National Institute of Justice Standards, along with the prior art, and may be contained or enclosed by a weather-resistant material.

In one aspect of the present invention, there is disclosed a method for forming plastic into either a multiple skin configuration, usually two skins, which may also have contained therebetween either an expandable plastic material, along with the anti-ballistic material reinforcement for strengthening the plastic article, other filler materials, or combinations thereof. In addition to the materials which can be incorporated into the middle layer between two skins, the present invention also discloses the use of many embedded articles to be placed between the two skins, whether they are completely embedded into the article, or whether portions of them are allowed to extend therethrough outside the molded article, i.e. for purposes such as securements, or vehicle mounting brackets, electrical wires, and the like.

In carrying out this embodiment, a double-skinned article can be manufactured using complementary male and female complementary molds above, with the introduction of a plastic filler material onto one of the molds prior to holding the molds together, such that there is a "sandwich" which is formed from these plastic composites. The double-skinned embodiment may also further comprise an expandable plastic filler material which will give a double-skinned plastic article with an anti-ballistic material incorporated into the expanded plastic filler material therebetween. A predetermined thickness for the expandable plastic is created by holding the male and female molds at a predetermined distance apart. In yet another embodiment, multiple types of anti-ballistic materials can be embedded into the plastic filler material or into the expandable plastic filler material such that, during manufacture, when the expandable material is heated and expanded up around the anti-ballistic material being encapsulated by the expanding foam material in between the two outer layers, the anti-ballistic material reinforcement is embedded into and surrounded by the expandable plastic filler material.

Experiments have shown that one aspect of the present invention shown in Fig. 2 has an anti-ballistic effect even when numerous bullets were pumped into a one square foot area with only the very slightest of deformation on the side opposite where the bullets entered the structure. In addition, the bullets entered through a plastic outer coating. In one aspect of the invention already tested, and the bullets were trapped in the plastic because the plastic re-melted back over the hind end of the bullet after the bullet was caught by the anti-ballistic material that was enclosed therein. The extreme heat that is given off by the absorption of the energy from the bullet re-melted the plastic and surrounded the rip in the outer skin, without any ricochet effect whatsoever. This backface deformation signature is reputedly a very good characteristic of my concept because the material causes the leading edge of the projectile to expand such that the expanded leading edge has more surface area. This allows more of the anti-ballistic material to engage the projectile and increase the stopping power of the material. In the present invention, an additional advantage arises because, when using a plastic exterior covering, the plastic melts when the bullet goes through and then re-melts when the energy has been absorbed from the force of the bullet, thereby encasing the bullet and eliminating any

ricochet. As other materials are used in the outer covering, more experiments will need to be done to establish this ricochet effect.

The foregoing description of a preferred embodiment of the invention has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed. Obvious modifications or variations are possible in light of the above teachings with regards to the specific embodiments. The embodiment was chosen and described in order to best illustrate the principles of the invention and its practical applications to thereby enable one of ordinary skill in the art to best utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated.

### **INDUSTRIAL APPLICABILITY**

The present invention finds industrial applicability in anti-ballistic materials and military applications to save the lives of soldiers and reduce the expense of military equipment.

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**CLAIMS**

1. An anti-ballistic article, comprising:

a first outer skin of polyolefinic material;

5 a second outer skin of polyolefinic material opposite said first outer skin;

an expandable material between the first and second skins;

at least one layer of anti-ballistic material embedded in the expandable  
material and being encased between the first and second skins,

10 whereby an anti-ballistic article is formed having superior anti-ballistic  
retention properties.

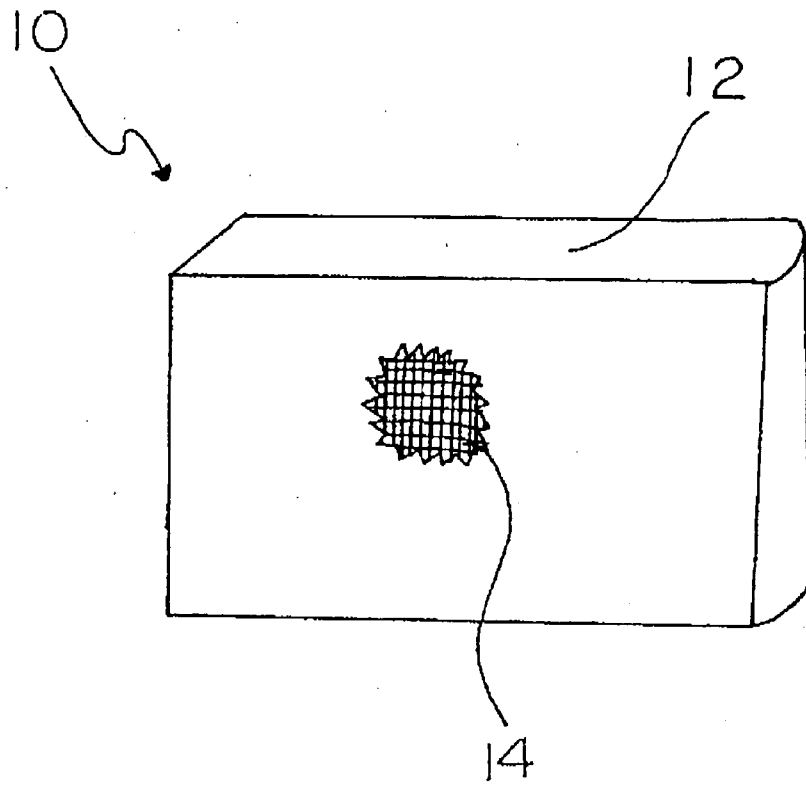


FIG. 1

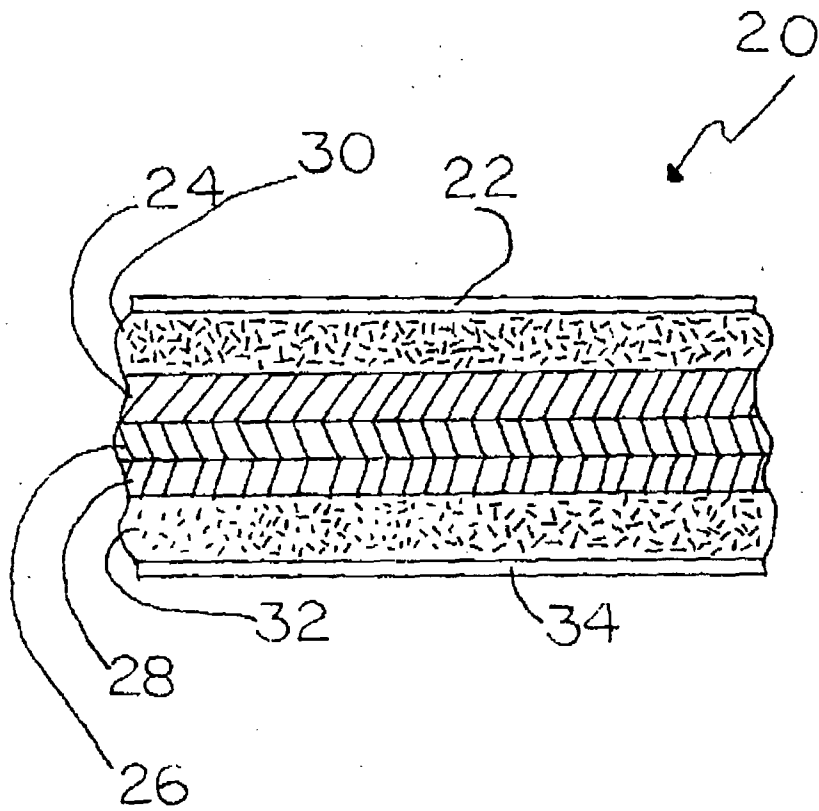


FIG. 2

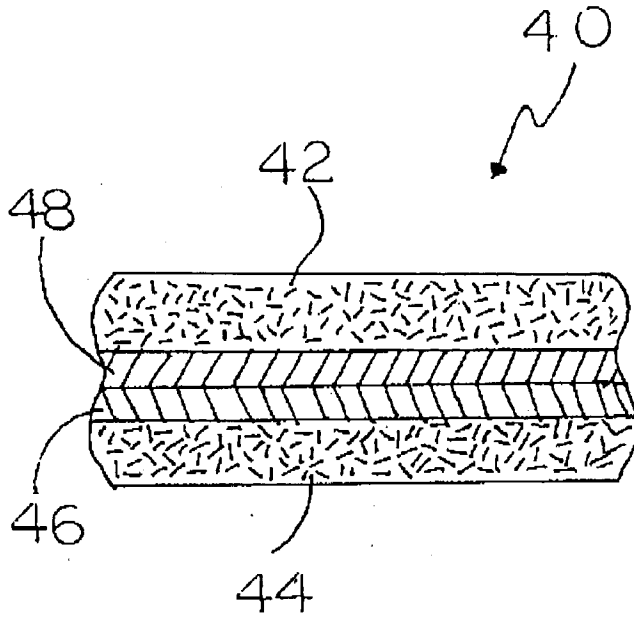


FIG. 3

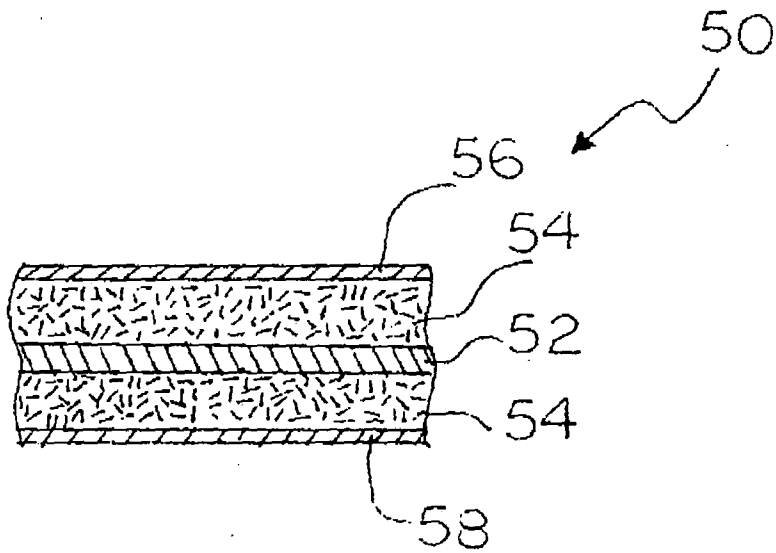


FIG. 4