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(54) **ARMOUR FOR HIGH ENERGY BULLETS AND PROJECTILES**

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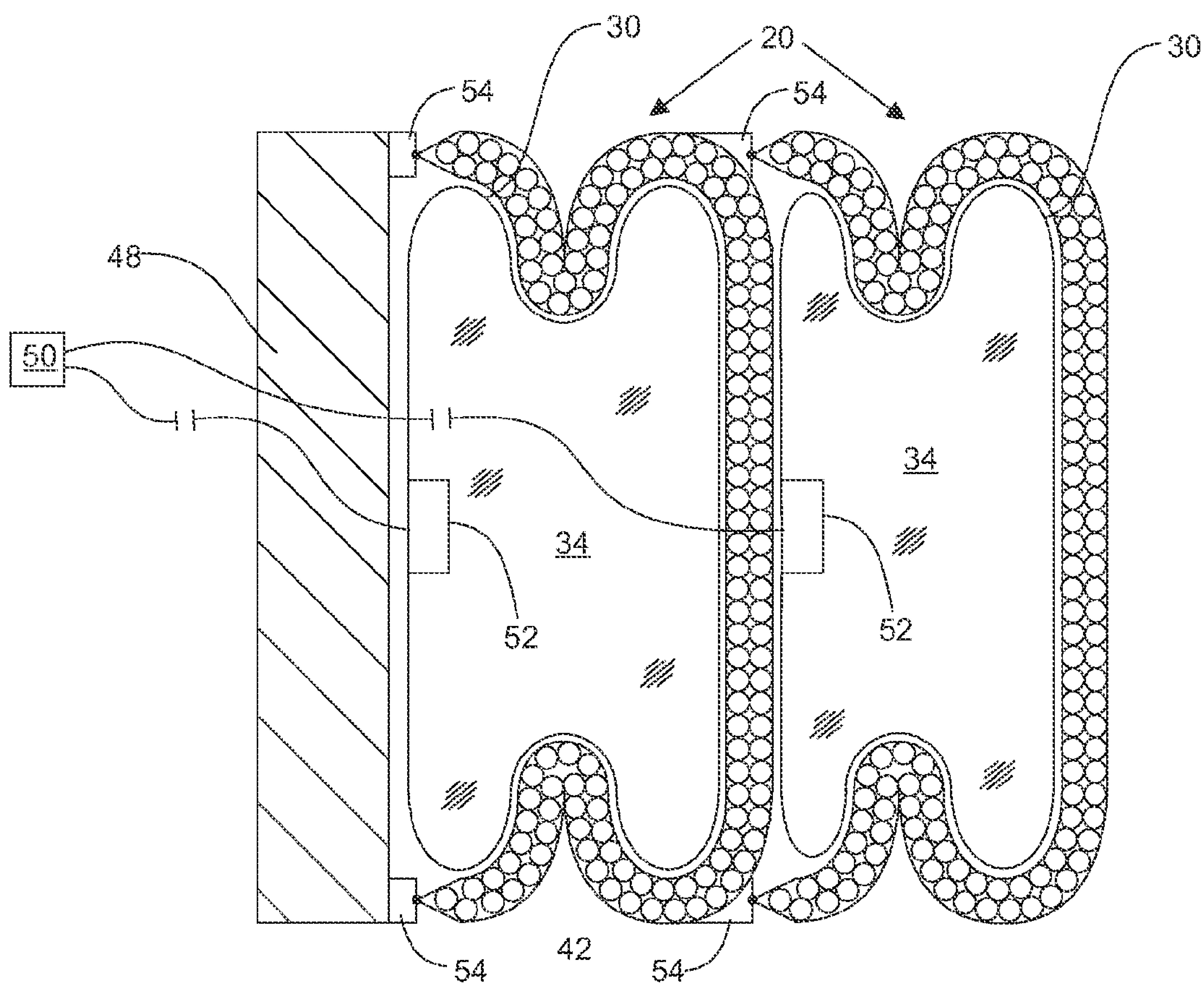
(57) **ABSTRACT**

Described is a flexible armour useful in protecting persons and vehicles from bullets and projectiles. The comprising an inner and an outer component, the outer component comprising at least two layers of hard solid beads confined between at least two layers of flexible high impact cloth, and the inner pneumatic component comprising a compartment that is an airtight compartment and/or that is an inflatable compartment. The armour is lightweight and flexible, and can stop a high energy projectile with little or no blunt trauma injury to the wearer of the armour.



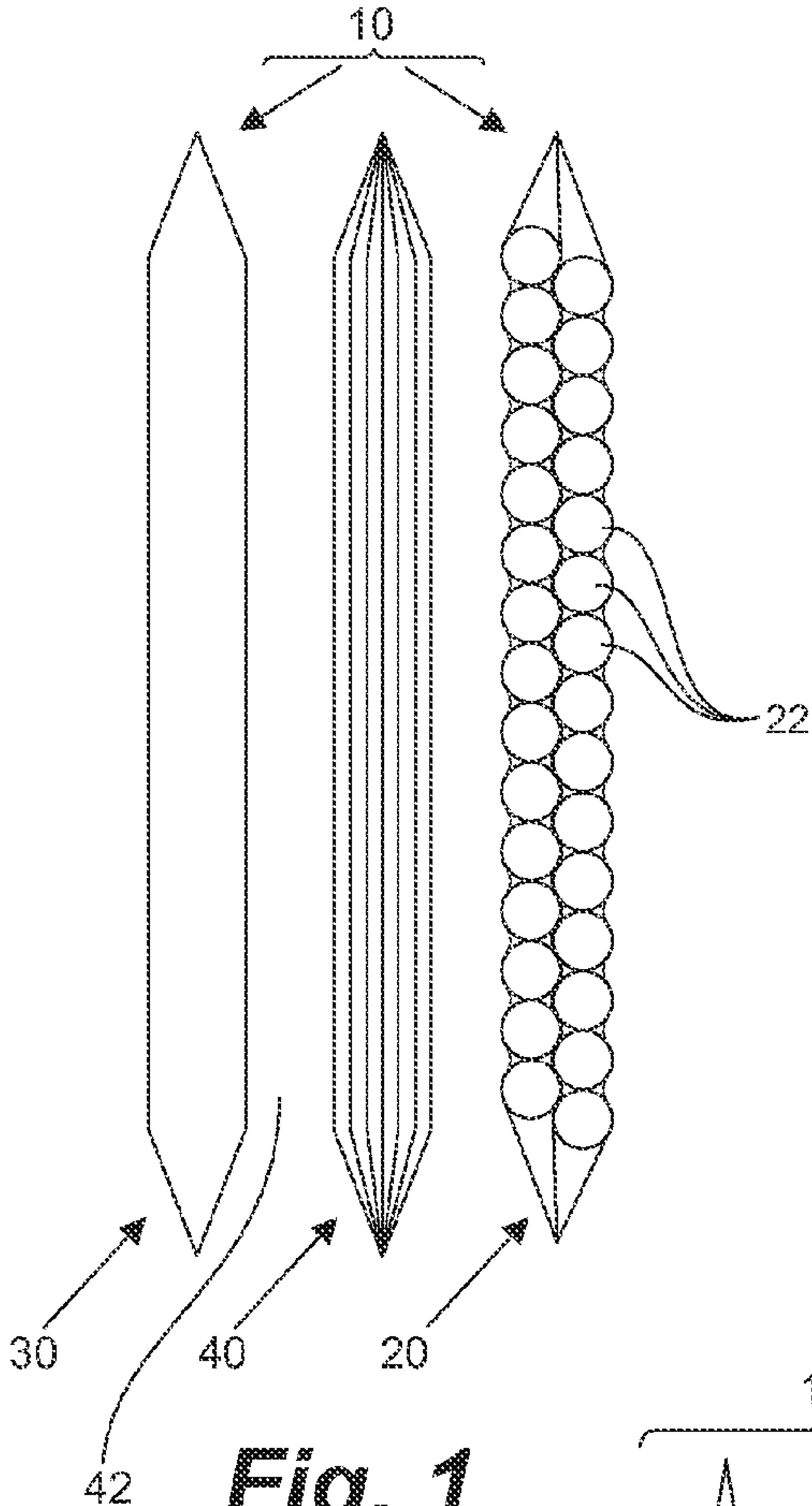


Fig. 1

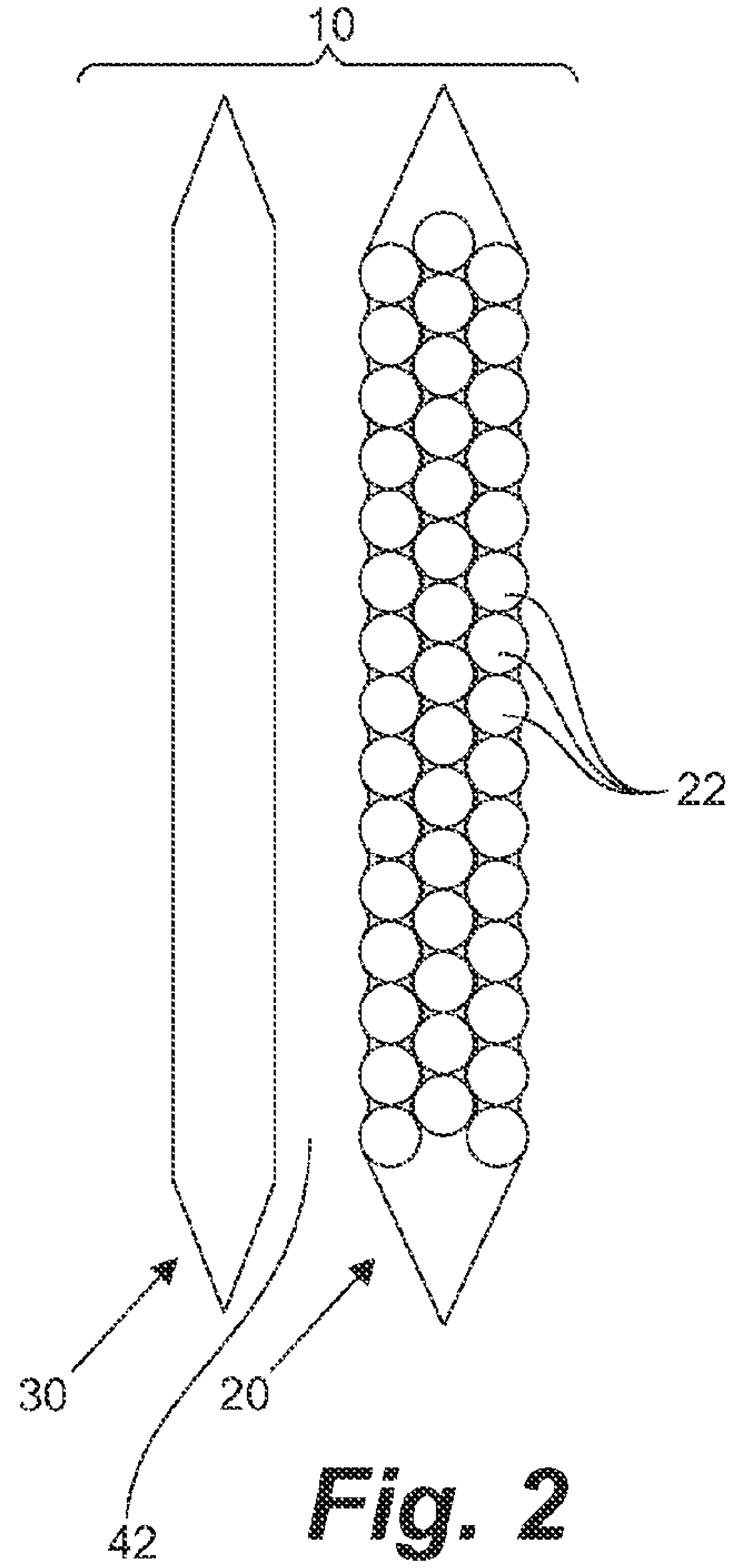


Fig. 2

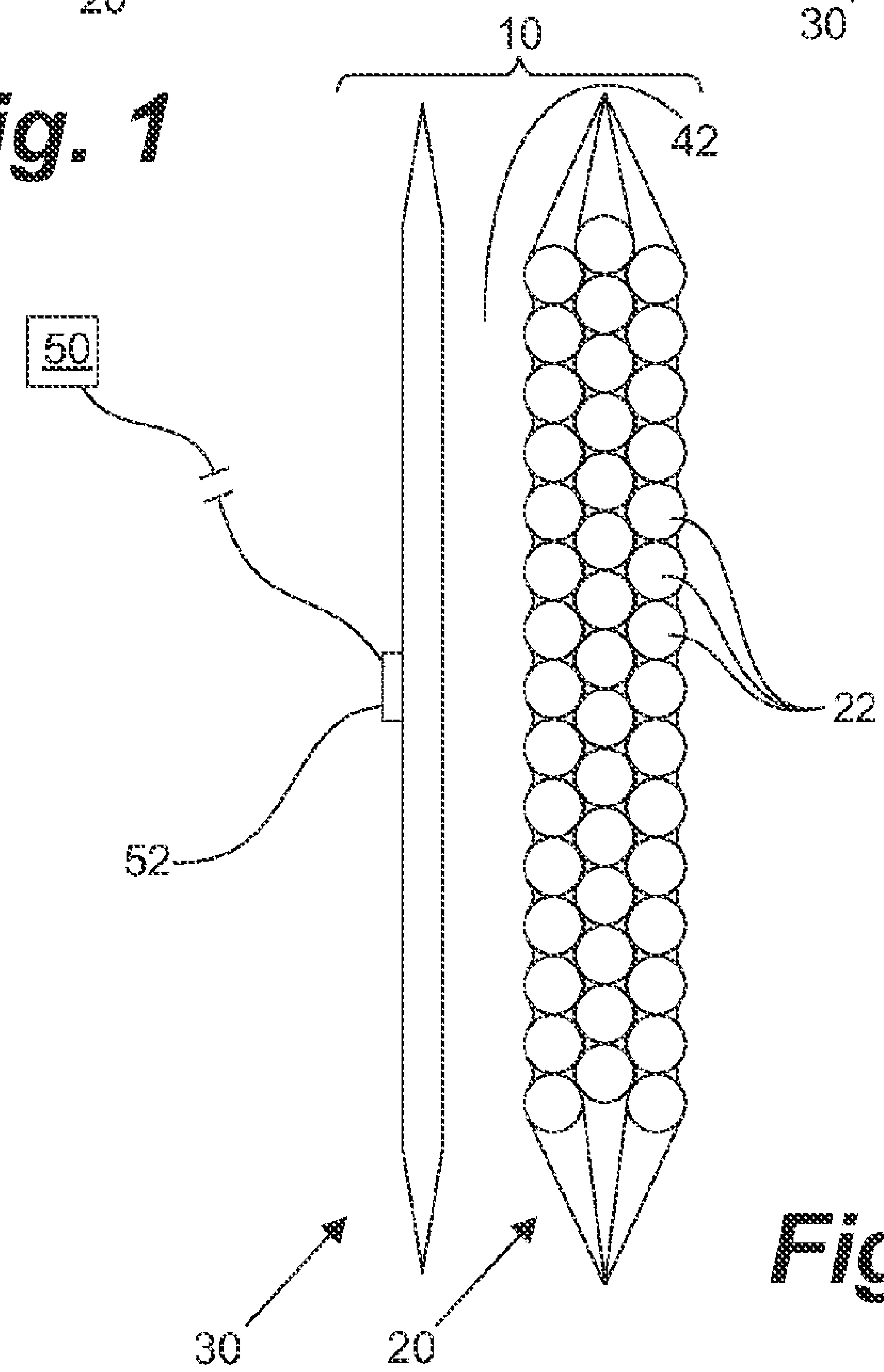


Fig. 3

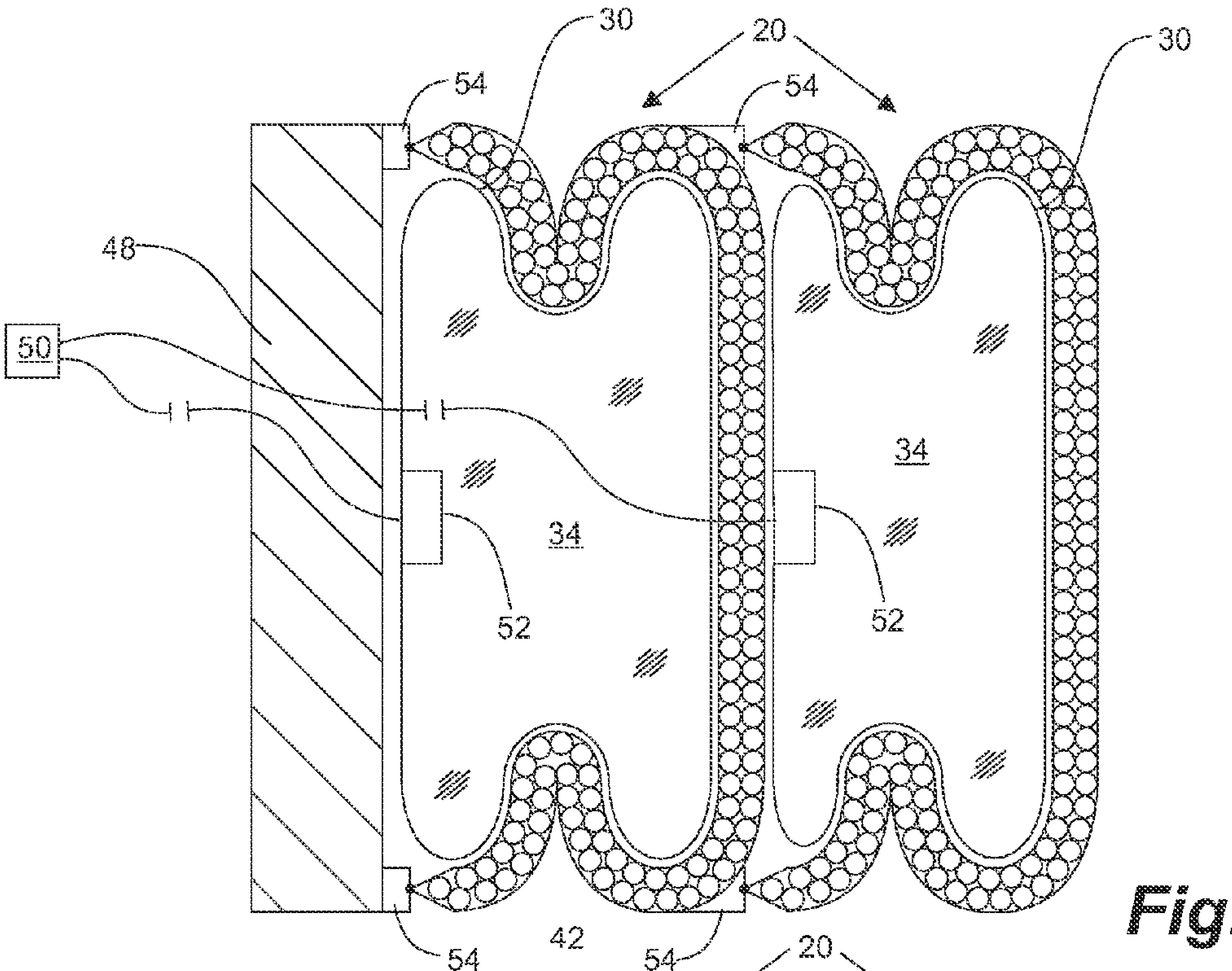


Fig. 4A

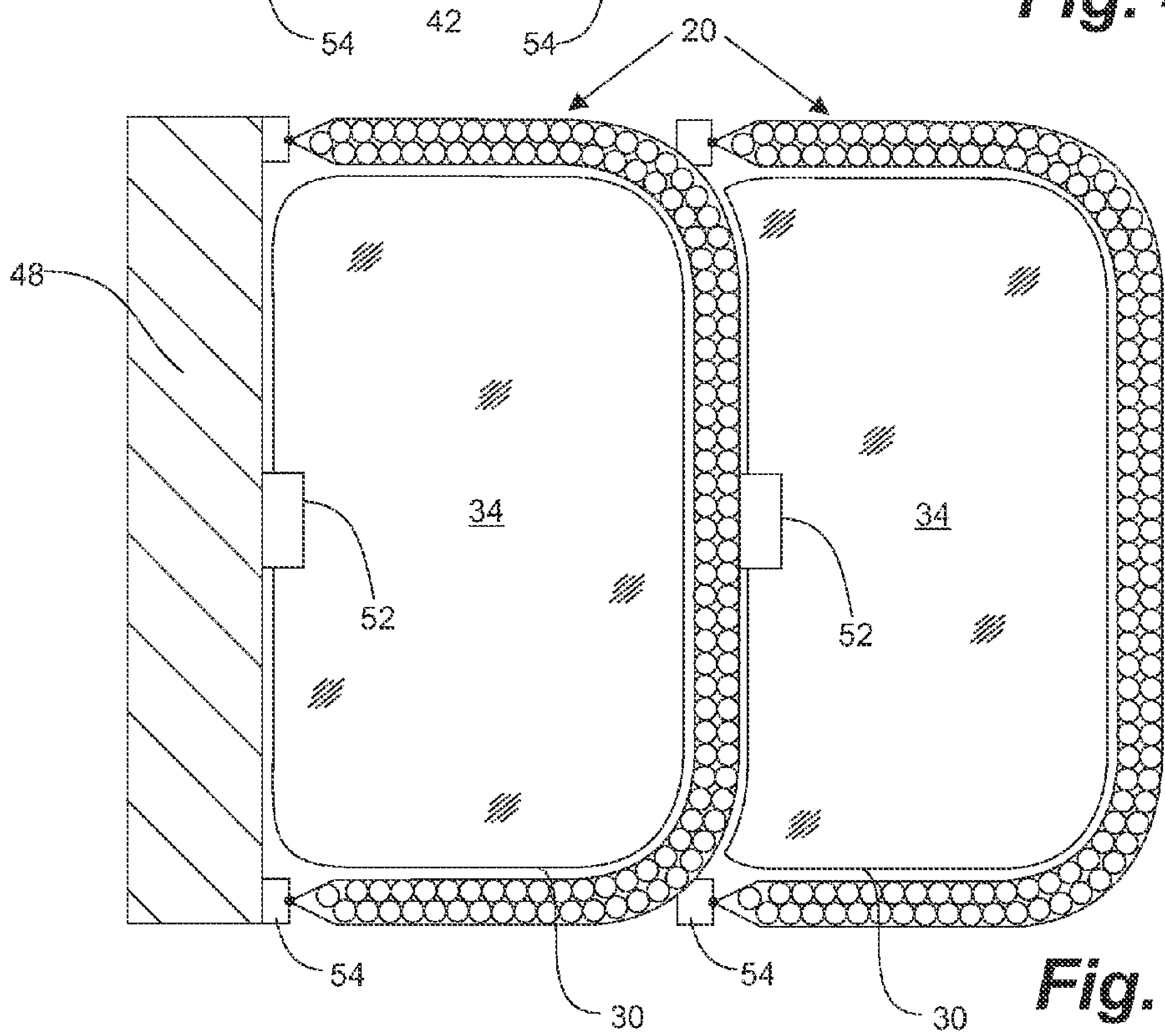


Fig. 4B

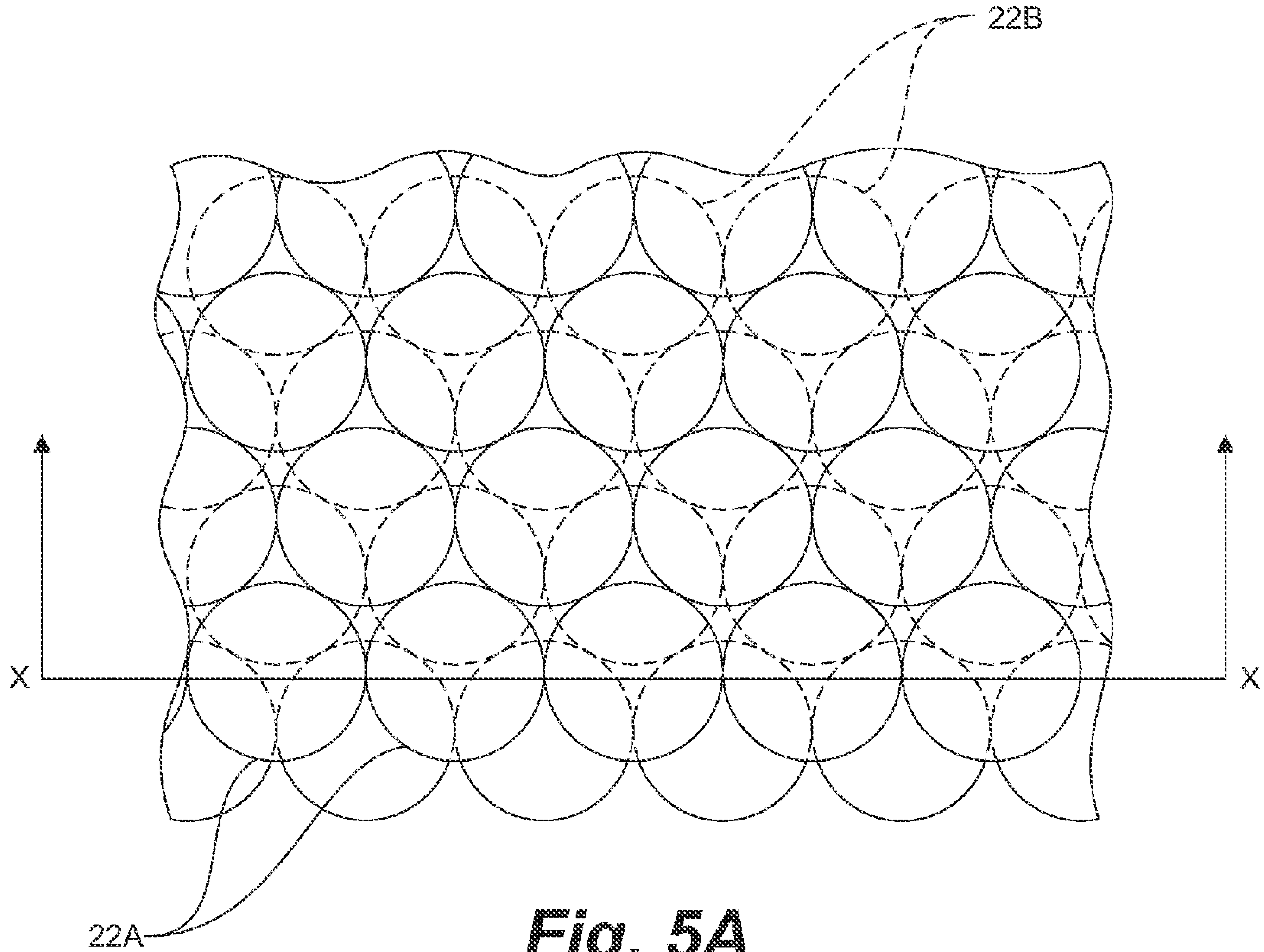


Fig. 5A

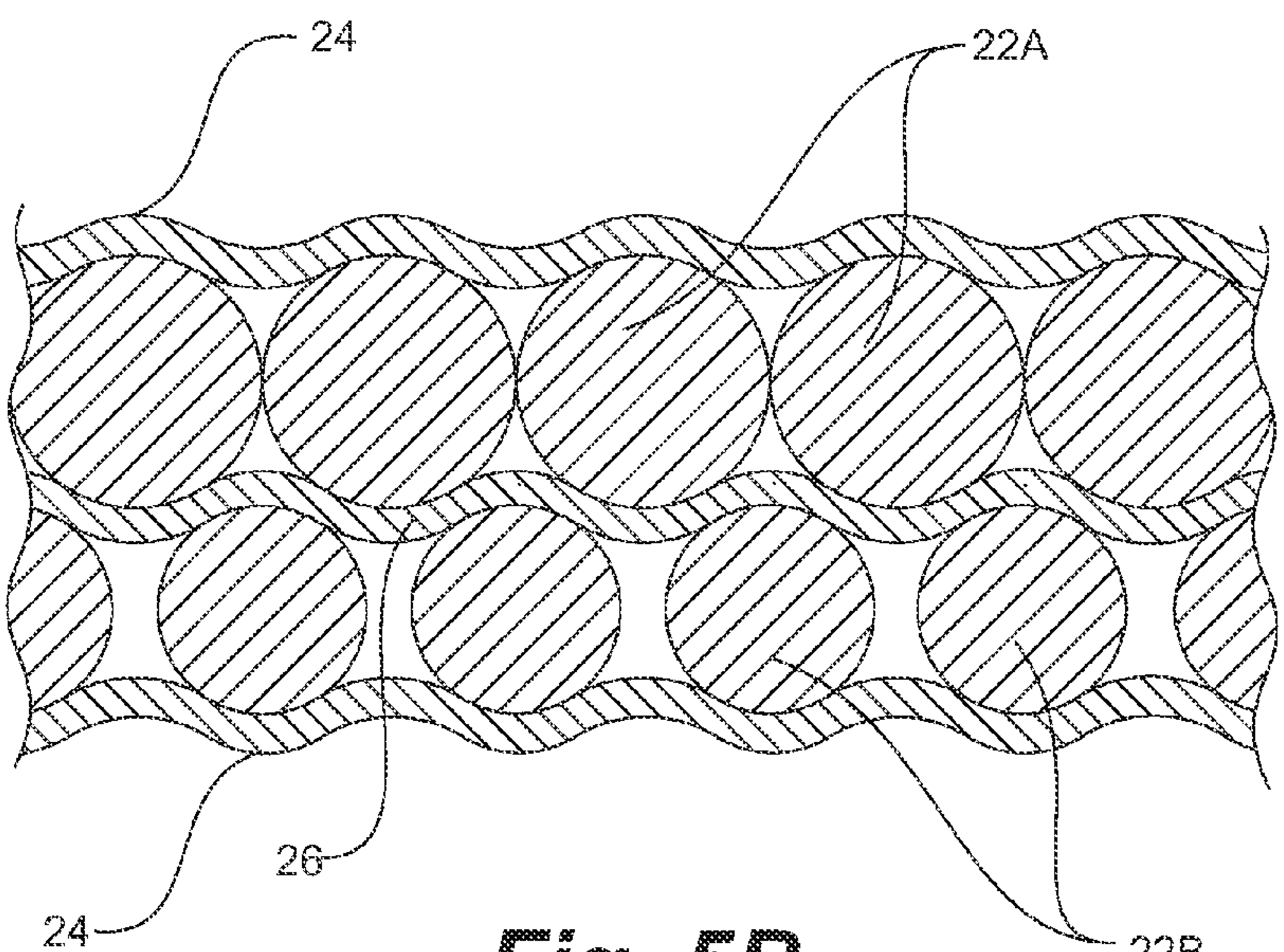


Fig. 5B

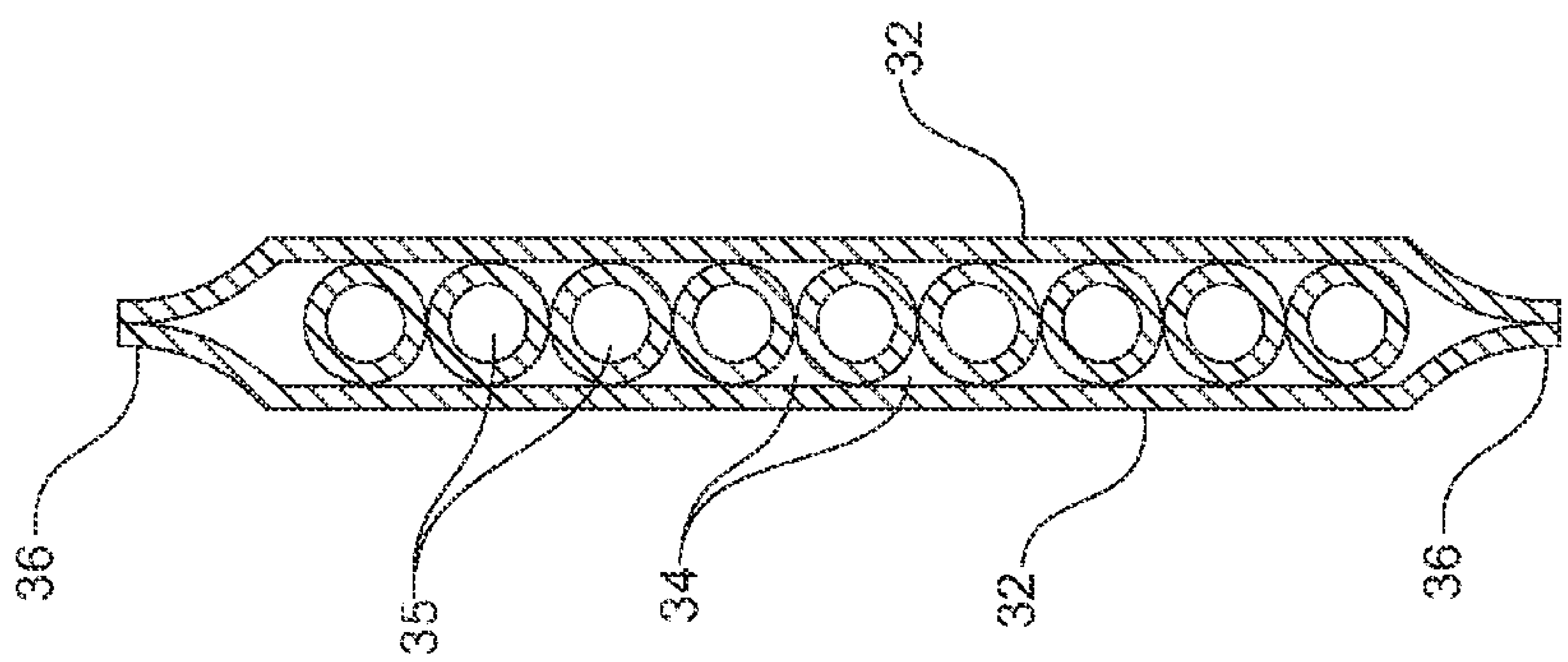


Fig. 6D

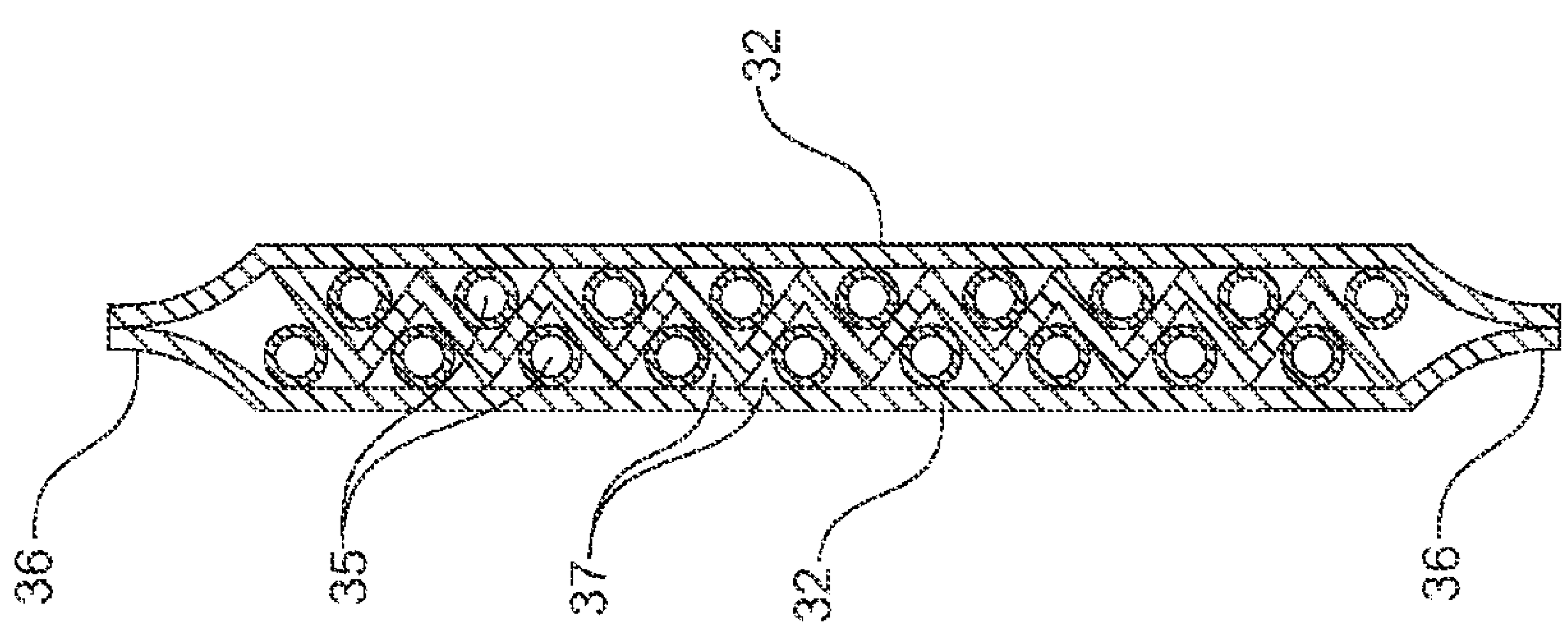


Fig. 6C

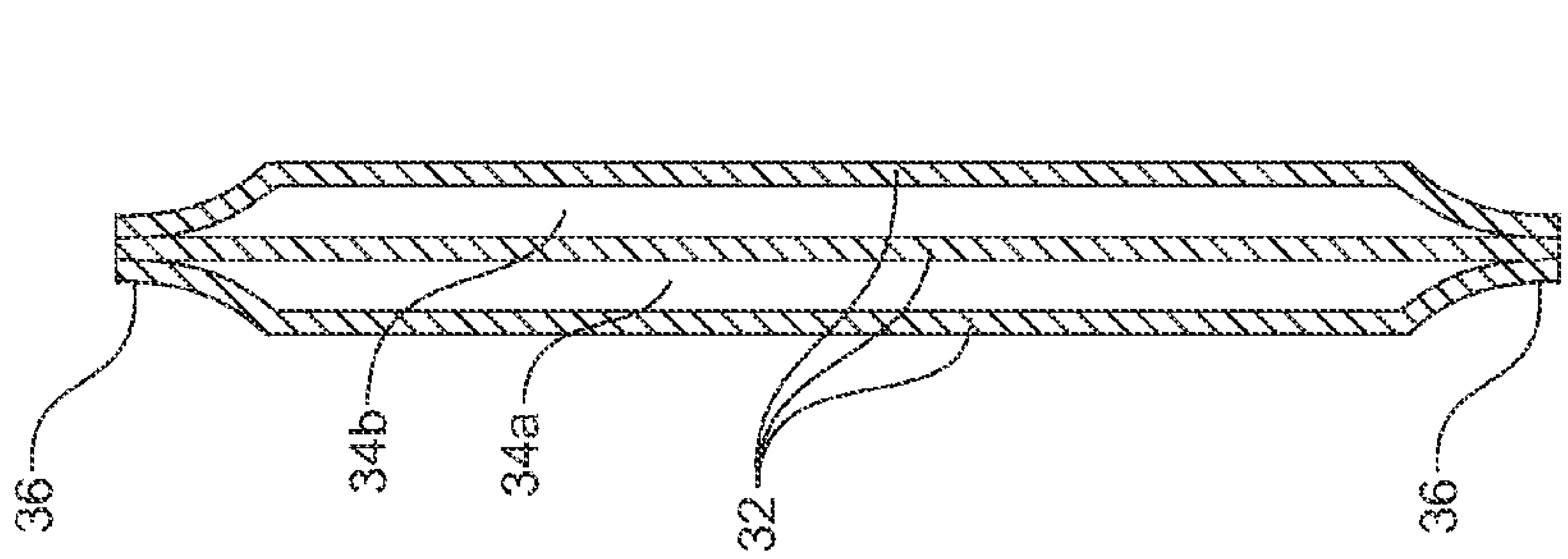


Fig. 6B

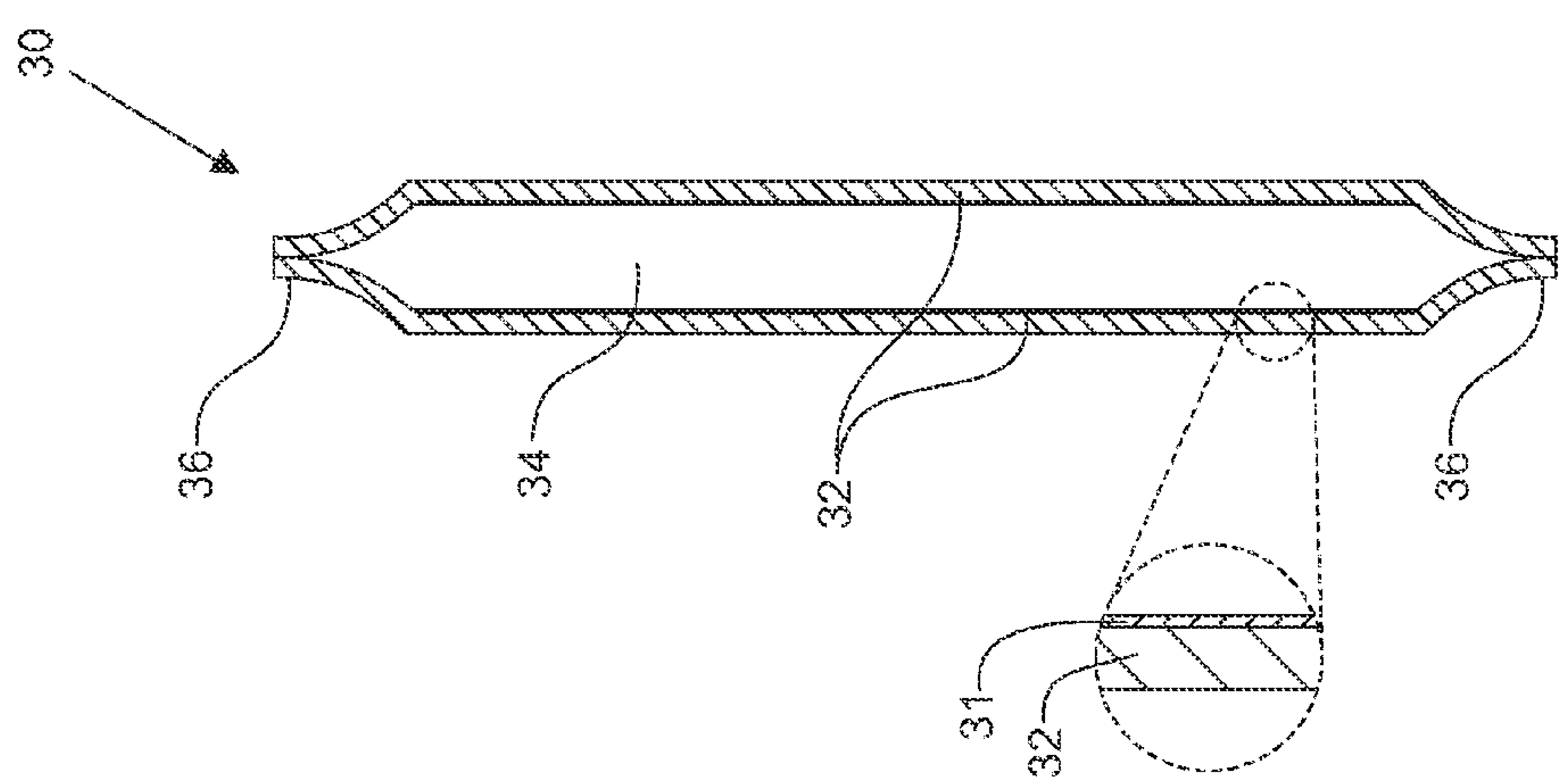


Fig. 6A

ARMOUR FOR HIGH ENERGY BULLETS AND PROJECTILES

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 61/833,510 filed on Jun. 11, 2013, the entire disclosure of which is incorporated herein by reference.

FIELD

[0002] The invention described herein relates to barriers or armour used to protect living beings, vehicles or equipment, from injury or damage caused by the impact of bullets or other high-speed projectiles. More particularly, the invention relates to a barrier or armour that reduces the speed and energy of the shock wave that results from projectile impact by absorbing the kinetic energy received from the projectile, and/or spreading the kinetic energy received from the projectile to a much larger area.

BACKGROUND

[0003] Many different types of soft armour have been used in the past, and provide a lightweight and relatively effective capability to stop ballistic projectiles such as bullets. These armours are capable of stopping passage of bullets of varying sizes and speeds. However, while capable of stopping a ballistic projectile, soft body armours suffer from the problem that they do little or nothing to stop, reduce and/or mitigate the transfer of kinetic energy from the ballistic projectile to the tissue which it is intended to protect. In other words, even when a soft armour is able to stop a bullet, the bullet can cause blunt trauma to underlying tissues, which can cause injury or death. This is particularly true when the bullet is a high energy bullet

[0004] Modern body armour uses KEVLAR® and other advanced fiber materials of high tensile strength to provide lightweight yet effective protection. It is also known to use hard glass spheres as an armour component (e.g., U.S. Pat. No. 5,110,661) and to use frangible materials, or pneumatic barriers, as armour components (e.g., U.S. Pat. Nos. 4,090,005; 5,059,467). It is known to use ballistic gels to reduce blunt trauma injury; however these are comparatively heavy in a body armour. Blast ceramic has also been used; however it is comparatively a hard material.

[0005] What is needed is an improved lightweight body armour that can not only stop a high energy projectile, but that can avoid or reduce blunt trauma injury to underlying tissues in the wearer of the armour.

[0006] What is also needed is an improved armour that can be used as a barrier to protect vehicles, equipment or buildings, from injury or damage caused by the impact of bullets or other high-speed projectiles.

SUMMARY

[0007] Described herein is a flexible, lightweight armour that can be used as a body armour or as a barrier to protect vehicles or equipment. When used as a body armour, the armour will avoid or reduce blunt trauma injury to underlying tissues in the wearer. When used as a barrier on vehicles, equipment or buildings, it will avoid or reduce damage to these structures.

[0008] The armour is made of an outer component that comprises layers of hard, solid beads and an inner component that is a pneumatic layer. The outer component is positioned in front of the inner component to receive the first impact of a bullet or other projectile. The outer component traps and destroys the structural integrity of the bullet or projectile. The inner component spreads the impact energy from the bullet or projectile thereby minimizing or avoiding damage to structures or persons being protected by the armour.

[0009] In one aspect the invention is a flexible armour comprising an inner and an outer component:

- **[0010]** the outer component comprising at least two layers of hard solid beads confined between at least two layers of flexible high impact cloth, and
- **[0011]** the inner component comprising a compartment that is an airtight compartment and/or that is an inflatable compartment.

[0012] The airtight compartment may be confined between at least two layers of flexible high impact cloth. One or more layers of flexible high-impact cloth may be disposed between the outer component and the inner component, and/or on the outer surface of the outer component, and/or on the inner surface of the inner component. Preferred flexible high-impact cloths are KEVLAR and/or SPECTRA.

[0013] In some embodiments the compartment of the inner component may airtight and may be filled with air or gas. Alternatively, in some embodiments the compartment of the inner component may be inflatable, and the armour may be equipped with a sensor that detects a bullet or other projectile before it contacts the armour, and that triggers inflation of the compartment with air or gas before the bullet or other projectile contacts the armour.

[0014] In some embodiments the beads used in the outer component are made of SPECTRA, ALON, aluminum, polycarbon, carbon fibre or ceramic beads. The beads can be coated with carbon nanotubes. Further, in some embodiments the at least two layers of beads in the outer component can be separated from each other by at least one separating layer comprised of a flexible high impact cloth such as KEVLAR and/or SPECTRA.

[0015] In some embodiments the compartment of the inner component may further be divided into two or more subcompartments. These subcompartments may be formed, in some embodiments, by hollow spheres disposed within the compartment or by a layer of high-impact cloth disposed within the compartment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. **1** is a cross section through an embodiment of an armour having an outer component comprising two layers of beads, a pneumatic layer inner component. Several layers of high-impact cloth, such as KEVLAR®, are disposed between the outer and inner components.

[0017] FIG. **2** is a cross section through an embodiment of an armour having an outer component comprising three layers of beads and a pneumatic layer inner component.

[0018] FIG. **3** is a cross section through an embodiment of an armour having an outer component comprising three layers of beads and a pneumatic layer inner component, wherein the pneumatic layer component is inflatable.

[0019] FIG. **4** is a cross section through an embodiment of an armour disposed on the surface of an armoured vehicle, the armour having two outer components comprising layers of beads and two pneumatic layer inner components. FIG. **4**A shows the pneumatic layers before inflation, and FIG. **4**B shows them after inflation.

[0020] FIG. **5**A is a top plan view of an embodiment of an outer component comprising two layers of beads. FIG. **5**B is a cross section through these layers showing the arrangement of the beads and the layers of SPECTRA® around the beads layers.

[0021] FIG. **6**A is a cross section of an embodiment of a pneumatic layer component having one compartment formed of two layers of SPECTRA®. FIG. **6**B is a cross section of a pneumatic layer component having two subcompartments formed by three layers of SPECTRA®. FIGS. **6**C and **6**D are cross sections an embodiments of a pneumatic layer component that comprise a plurality of subcompartments.

DETAILED DESCRIPTION

[0022] Described herein is an armour **10** that includes layers of hard, solid beads as an outer component **20**, and a pneumatic layer as an inner component **30**. The outer component **20** is positioned in front of the inner component **30**, "in front" meaning that the outer component is the first component to receive the impact of a bullet or other projectile. The armour **10** may be a component of a body armour or barrier, used in conjunction with other components.

[0023] The armour may be configured as a soft body armour, more specifically a lightweight and flexible ballistic panel, which can stop a projectile and which can avoid or reduce blunt trauma injury to underlying tissues.

[0024] The armour may be configured as a barrier, to protect vehicles such as light armoured vehicles and personnel carriers, or equipment, from injury or damage caused by the impact of bullets or other high-speed projectiles.

[0025] The layers of beads are the outer component of the armour, and are designed to trap the bullet or projectile. As a bullet or other projectile passes through the layers of beads, the bullet is destroyed—flattened, shredded or mulched—and trapped in the layers of beads. The pneumatic layer is the inner component of the armour and it is designed to spread the impact energy from the bullet or projectile that hits the outer component. The outer component and inner component may be designed on any scale of size for use in protecting various things, such as persons, motor vehicles, ships, aircraft, buildings, etc. The armour may be any shape, including square, rectangular, circular, oval and triangular.

[0026] FIG. **1** is a cross section through an embodiment of the armour **10** which embodiment has an outer component **20** comprising two layers of beads **22** and a pneumatic layer inner component **30**. In this embodiment several layers **40** of KEVLAR® or other high impact cloth are disposed between the outer and inner components of the armour **10**.

[0027] In the FIGURES, spaces **42** are shown between the layers **20**, **30** and **40** for illustrative purposes, however in actual assembly these layers will be in close contact with one another. As is apparent, additional layers of protective material may be inserted between or on either side of these layers, provided that in accordance with the invention described herein, the outer component of beads is positioned in front of the inner pneumatic layer component.

[0028] FIG. **2** is a cross section through an embodiment of the armour **10**, which embodiment has an outer component **20** comprising three layers of beads **22** and a pneumatic layer **30** as an inner component. This armour differs from that of FIG. **1** in that layers of flexible high-impact cloth are not disposed between the outer and inner components of the armour, which are in close contact with one another. Additional layers of protective material such as several layers **40** of KEVLAR®, may be inserted on either side of the armour **10**, or between the two components of the armour **10** (as shown in FIG. **1**), provided that in accordance with the invention described herein, the outer component of beads is positioned in front of the inner pneumatic layer component.

[0029] FIG. **3** is a cross section through an embodiment of the armour **10**, which embodiment has an outer component **20** comprising three layers of beads **22** and a pneumatic layer as an inner component **30**, wherein the pneumatic layer is inflatable. This vest has the advantage that it is thinner than the embodiment shown in FIG. **2**.

[0030] The inflatable pneumatic layer **30** in the embodiment shown in FIG. **3** is equipped with a sensor **50**, which can detect an incoming bullet and, in response, trigger a charge **52**, to deploy air or a gas such as nitrogen, carbon dioxide or other suitable gas that will inflate and pressurize the compartment in the pneumatic layer. The air or gas may be contained within a pressurized container connected via a fluid passageway to the compartment. Sensor **50** can be a diaphragm sensor (pressure, shock wave), optic (light, flash, movement, heat, shock wave), radar cell phone frequency (disruption of microwave) or other type of sensor that is capable of detecting an incoming bullet, and causing the charge to inflate and pressurize the pneumatic layer in time to capture the energy transferred from the outer layer of beads. Sensor **50** can be powered by a battery or other power source. Charge **52** can be a cordite or smokeless charge or other type of charge.

[0031] At least two layers of beads **22** are used to form the outer component. Optionally, three to six layers of beads are used. These at least two layers of beads are confined between a least two layers of flexible high impact cloth. FIG. **5**A shows a top view of an outer component **20** comprising two layers of beads **22**, where the beads are arranged in layers, between sheets of flexible high impact cloth, such as SPECTRA®. The top layer of SPECTRA® is removed in the embodiment shown in FIG. **5**A, to show the underlying two layers of beads. More layers of beads may be used. The upper layer of beads **22**A is shown above the lower layer of beads **22**B.

[0032] The beads are preferably of uniform diameter, and are arranged in a non-random closely-packed lattice pattern in which each bead is in immediate contact with all of its neighbouring beads, thereby minimizing the size of inter-bead spaces in a layer and between layers. As shown herein, the layers of beads in the outer component may directly contact one another, or they may be separated by one or more layers of a flexible high-impact cloth. While the layers of beads used in an outer component are preferably of uniform diameter it is contemplated that the layers may comprise beads of different diameters. For example, smaller beads may be used to fill inter-bead spaces formed between layers of larger beads in an outer component.

[0033] Interspersed between the layers of beads may be a flexible high-impact cloth such as SPECTRA®, carbon fiber, KEVLAR®, spider fiber, GOLDSHIELD®, GOLD FLEX®, TWARON® and DYNEEMA®. The flexible high-impact cloth may be in between each layer of beads, or between every second or third layer of beads. In alternative embodiments the layers of beads are not separated by one or more layers of flexible high impact cloth.

[0034] In a particularly preferred embodiment, one layer of beads is manufactured by bonding a layer of beads between two layers of SPECTRA®. This may be accomplished, for example by laying a first sheet of SPECTRA® onto a mold designed to hold the beads and arrange them in a regular pattern. The beads are positioned in the mold, and a second layer of SPECTRA® is laid on top of the arranged beads. Heat may then be applied to these layers of SPECTRA® to cause them to melt or soften, and bond to the beads. In this preferred embodiment, one layer of beads thus prepared is then laid on top of one or more other layers of beads, to form the outer component of an armour. These may be secured together for example by using additional layers of SPECTRA® and bonding these to the other layers of SPECTRA®, using heat. In some embodiments, and depending on the materials used, radio frequency waves may be used to bond the beads to the high-impact cloth that may be interspersed between and over the layers of beads. The layers of beads may also be prepared by lamination, for example with a nano-carbon film.

[0035] FIG. **5**B shows a cross section between the two layers of beads taken at line X-X in FIG. **5**A and manufactured according to the process described above. The upper layer of SPECTRA® **24**, which had been removed from FIG. **5**A is shown as well. In this embodiment, the beads are separated by one layer **26** of SPECTRA® and covered on either side by one layer of SPECTRA® **24**.

[0036] Beads **22** are solid, hard objects with a spherical shape, such as round or oval. They can be made of steel, aluminum, aluminum oxide and other metals or combinations of metals (i.e., aluminum bead coated with aluminum oxide; nickel or copper plated steel beads), plastic, glass, ceramic. Specific examples of preferred materials for making beads are ALON® (Surmet Corporation) a ceramic that is based on a composition of aluminum oxy nitride with a cubic spinel crystal structure and SPECTRA®, a thin, flexible ballistic composite made from layers of unidirectional fibers held in place by flexible resins (Honeywell International Inc.). Other embodiments of beads comprise a carbon fiber centre with a polycarbon outer layer. Yet other embodiments comprise a polycarbon, carbon fibre or ceramic bead. Any of the beads may be coated with carbon nanotubes.

[0037] In some embodiments the layers of beads in the outer component may be separated by layers of flexible material. However, in all embodiments the beads of the outer component are able to move and impact each other (sometimes via intervening layers of flexible high-impact cloth) when a bullet or projectile impacts the outer component. This movement of the beads relative to one another results in multiple impacts of the bullet with the beads, and of the beads with each other, thus resulting in dissipation of the energy from the bullet and distortion of the bullet as it becomes distorted and trapped by the outer component. As noted above, the beads are packed in a non-random closely-packed lattice pattern, and they are confined between at least two layers of flexible high impact cloth. Applicant has found that an outer component comprised of beads having a random packing pattern or in which the beads are not closely-packed or in which the beads are not confined, is not as strong as one in which the beads are tightly packed in a non-random closely-packed lattice pattern and which constrains or confines the ultimate movement of the beads.

[0038] The outer component may be permanently attached to the front of the inner component, or optional intervening layers (e.g., layers of high-impact cloth) for example by stitching. Alternatively, it may be reversibly attached to the inner component or optional intervening layers by VELCRO®, or by slipping the outer component into a suitably sized sleeve that is positioned in front of the inner component and intervening layers if incorporated.

[0039] In one embodiment, a ballistic gel may be used between the beads. In another embodiment, aluminum mesh may be used between the layers of beads.

[0040] The pneumatic layer component **30** comprises trapped air, nitrogen gas, carbon dioxide or other suitable gas disposed inside a compartment that is airtight or in the case of pneumatic components that are inflatable that can be inflated with air, nitrogen gas, carbon dioxide or other suitable gas. The compartment may be disposed between two layers of flexible high-impact cloth or another flexible material (e.g., nylon, plastic). High-impact cloth materials useable in making the pneumatic layer include SPECTRA®, KEVLAR®, spider fiber, GOLD SHIELD®, GOLD FLEX®, TWARON®, DYNEEMA®, carbon nanotubes, carbon nanoballs, buckminsterfullerene (Buckyballs). Sheets of these materials may be laminated with a material to make them airtight, for example a plastic, for example polyethylene, nylon, polycarbonate or polyurethane. FIG. **6**A (inset) shows an airtight laminate layer **31** disposed on the inside surface of the layer of the high-impact cloth **32**. Alternatively airtight tightly woven cloths, such as nylon or Dacron, may be used in place of plastic, disposed either inside or outside of the high-impact cloth material.

[0041] After making the high-impact cloth materials airtight, one sheet, or two or more sheets may be sealed together around the edges using a bonding agent, such as a flexible thermoplastic material, such as polyurethane, polyester or polyethylene, to make an airtight hermetically sealed compartment. Air or gas may then be injected into this compartment, to form the pneumatic layer component **30** in the case where this component is not inflatable. Alternatively, the high-impact cloth materials may be sealed together around the edges using a bonding agent, and then treated for example with a plastic material, to make the airtight hermetically sealed compartment. The air or gas in the compartment may or may not be pressurized.

[0042] In the case where the pneumatic layer component **30** is inflatable, it need not be airtight and can be made by sealing one sheet, or two or more sheets of material (e.g., nylon) together around the edges using a bonding agent, such as a flexible thermoplastic material, or by stitching. Air or gas may then be injected into this compartment when charge **52** is triggered by the sensor **50**, as is well-known by persons of skill in the art. After deployment the pneumatic layer component may deflate.

[0043] In a preferred embodiment the pneumatic layer is made using SPECTRA® as a supporting material. In this embodiment, SPECTRA® is laminated with a plastic material to make it airtight. Two or more layers of SPECTRA® are brought together, the edges are hermetically sealed and air or gas is injected between the layers of SPECTRA® to form the pneumatic layer component **30**.

[0044] The pneumatic layer component **30** is formed of one compartment **34**, as shown in FIG. **6**A, which shows a cross section of the component comprising two layers of laminated SPECTRA® **32** (or other high-impact cloth) around on internal compartment **34** containing air or nitrogen gas, with sealed edges **36**. This one compartment of the pneumatic layer component may be further compartmentalized into sub-compartments. Compartmentalization may be achieved for example as shown in FIG. **6**B, by using for example three sheets of laminated SPECTRA® **32**, and injecting gas or air between the three sheets to form two subcompartments **34***a* and *b*, inside the main compartment **34**.

[0045] The embodiment of the pneumatic layer component that is shown in FIG. **6**C comprises a series of circular subcompartments **35** inside a series of triangular subcompartments **37** disposed in the main compartment **34** of the pneumatic layer comprised of two layers of high-impact cloth that are sealed to form an airtight compartment. Circular subcompartments **35** may be formed as tubes, formed by circularizing a sheet of material and triangular subcompartments **37** may be formed by pleating a sheet of material. The spaces in the subcompartments of FIG. **6**C are filled with air or gas.

[0046] The pneumatic layer component may also include subcompartments that are formed from hollow soft- or hard-sided spheres **35** that are made of a material such as carbon fiber or SPECTRA®, and filled with air or gas such as nitrogen. These spheres are disposed in the main compartment **34** of the pneumatic layer comprised of two layers of high-impact cloth that are sealed to form an airtight compartment. The hollow spheres may be arranged in a layer or layers in the pneumatic layer as shown in FIG. **6**D.

[0047] A particularly preferred embodiment of the armour **10**, for use in a soft body armour comprises several layers of ALON beads bonded to SPECTRA®, as the outer component. This is placed is in front of a pneumatic layer inner component, that is made from laminated SPECTRA®, as described above. In between these two layers may be disposed several layers of KEVLAR®. A vest thus constructed avoids or reduces blunt trauma injury to underlying tissues in an individual who is shot with a high powered rifle round, such as a 50, 223, 308 or 338 caliber bullet. Other particularly preferred embodiments use SPECTRA®, carbon or aluminum beads in the outer component.

[0048] The armour **10** may also be used to protect a vehicle or structure from damage due to impact of projectiles or bullets. It is contemplated that one, or more than one, layer of armour **10** may be used on a vehicle. FIG. **4** shows a cross section of an embodiment of the armour applied to an armoured vehicle **48**. In this embodiment, two layers of armour **10** are used, each comprising an outer component of layered beads **20** and an inner pneumatic layer **30**. The outer components are fastened to the vehicle or to the other outer component, for example by using bolts **54** or VELCRO. In this embodiment the compartments **34** of the inner pneumatic layers inflate when triggered by a sensor that detects an incoming bullet or projectile. In a preferred embodiment, the beads of the outer layer are comprised of ALON that are bonded to SPECTRA®, carbon filter or KEVLAR®.

[0049] The pneumatic layers **30** in the embodiment shown in FIG. **4** are equipped with one or more sensors **50**, which can detect an incoming bullet or projectile and, in response, trigger charges **52** to deploy air or a gas such as nitrogen, carbon dioxide or helium, which will inflate the pneumatic layers. The sensor(s) **50** can be diaphragm sensors (pressure, shock wave), optic sensors (light, flash, movement, heat, shock wave), a radar cell phone frequency sensor (disruption of microwave) or any other type of sensor that is capable of detecting an incoming bullet or projectile and causing the charges to inflate the pneumatic layers in time to capture the energy transferred from the outer layer of beads. Sensors **50** can be powered by a battery that is the vehicle battery or an independent battery or other power source. Charges **52** can be a cordite or smokeless charge or other type of charge.

[0050] The sensors **50** can be designed to trigger the charges **52** in unison or sequentially, when they detect an incoming bullet or projectile.

[0051] In one embodiment of the armour **10** used for protecting vehicles or other structures, the outer beaded layer(s) are provided with an electric current that generates an electromagnetic field, for example by running copper wire through the layers of beads. The electromagnetic current will detonate the piezoelectric fuse on an incoming rocket-propelled grenade (RPG) before it contacts the outer beaded layer of the armour. The power source for the electromagnetic field can be the battery from the vehicle or an independent battery or other power source. In this embodiment, the energy in the RPG is substantially weakened before it first contacts the outer layer.

[0052] The armour **10** may additionally be designed to be a "reactive" armour, which is an armour that reacts in some way to the impact of a weapon to reduce the damage done to the vehicle being protected, such as an explosive reactive armour (ERA), self-limiting explosive reactive armour (SLERA), non-energetic reactive armour (NERA), non-explosive reactive armour (NxRA), and electric reactive armour.

[0053] A particularly preferred embodiment, for use on a light armoured vehicle, comprises two layers of armour **10**, each layer comprising an outer component comprised of layers of ALON beads, each positioned in front of a pneumatic layer inner component, which is inflatable. The armour **10** includes one or more sensors that sense the incoming projectile and cause the charges to inflate the pneumatic layer components before the projectile contacts the outer component of beads. If the armour additionally comprises an electromagnetic field, in the case of an incoming RPG, the field will detonate the piezoelectric fuse on the incoming RPG before it contacts the first outer beaded layer of the armour. In this embodiment, while it is conceivable that the projectile may penetrate the first outer component and pneumatic layer, it is anticipated that it will have lost sufficient energy in doing so, and will be sufficiently deformed by the beads, that it will be trapped by the second outer component.

[0054] The armour **10** therefore, disposed on a light armoured vehicle or armoured personnel carrier, will defeat or at least significantly reduce the impact of incoming RPGs, improvised explosive devices (IEDs) and 50 caliber bullets.

EXAMPLES

[0055] Following are representative examples of the invention.

No Pneumatic Layer

Example 1

[0056] Plastic AIRSOFT pellets, which are spherical projectiles used in AIRSOFT gun models, were put into a ZIPLOC® bag, to a thickness of about 1.5", and this bag was taped to the front of an RCMP KEVLAR® vest comprising **22** layers of KEVLAR®, which was secured to the front of a 10 L plastic water jug that was filled with water, with the pellets on the outside. A 223 caliber bullet was fired at this assembly from a distance of 25 meters, and the 223 caliber bullets were stopped and trapped in the pellets. Without the pellets in front, the bullets would have penetrated through the vest. However, the bullet would have caused severe, if not fatal, blunt trauma injury.

Example 2

[0057] Glass beads (marbles) were put into a ZIPLOC® bag, to a thickness of about 2.5" to 4", and this bag was taped to the front of an RCMP KEVLAR® vest comprising **22** layers of KEVLAR®, which was secured to the front of a 10 L plastic water jug that was filled with water, with the beads on the outside. 223, 308 and 338 Lapua Magnum bullets were fired at this assembly from a distance of 25 meters. Without the beads, the bullets would have penetrated through the vest. The bullets were stopped and trapped in the marbles, however the bullets would have caused severe, if not fatal, blunt trauma injury.

Example 3

[0058] 4.5 mm round steel beads were arranged in three layers. In between each layer was duct tape to hold the beads, and an aluminum mesh. The layers of beads were placed over an RCMP KEVLAR® vest comprising **22** layers of KEVLAR®. A 10 L plastic water jug was filled with water and a dye, and the combination of bead layers and vest was attached to the front of the water jug with the layers of beads on the outside. 223 caliber bullets (lead core or soft steel core) were shot at this arrangement from a distance of 25 meters, and failed to penetrate through the vest. Without the beads, the bullets would have penetrated the vest. However, the water jug was broken, indicating that the bullets would have caused severe, if not fatal, blunt trauma injury.

Example 4

[0059] 4.5 mm round steel copper-coated beads were arranged in sixteen layers by laminating the layers of beads together. These sixteen layers of beads were placed in front of a 10 L plastic water jug that was filled with water, with the layers of beads on the outside. A raw egg was positioned between the back of the water jug and a solid barrier. 308 caliber bullets were shot at this arrangement from a distance of 1 meter, and failed to penetrate the layers of beads. However, the water jug and the egg were broken, indicating that the bullets would have caused severe, if not fatal, blunt trauma injury.

With a Pneumatic Layer

Example 1

[0060] 4.5 mm round steel beads were arranged in three layers. In between each layer was an aluminum mesh and duct tape to hold the beads. The layers of beads were placed over an RCMP KEVLAR® vest comprising 22 layers of KEVLAR®, which was placed over three layers of conventional bubble wrap. A 10 L plastic water jug was filled with water and a dye, and the combination of the layered beads, vest and bubble wrap, was attached to the front of the water jug. 223 caliber bullets (lead core or soft steel core) were shot at this arrangement from a distance of 25 meters, and failed to penetrate through the vest. The water jug was not broken, indicating that the bullets would have caused minor, if any, blunt trauma injury.

Example 2

[0061] 4.5 mm round steel beads were arranged in six layers using duct tape. These six layers of beads were placed over an RCMP KEVLAR vest comprising 22 layers of KEVLAR®, which was placed over three layers of conventional bubble wrap. A 10 L plastic water jug was filled with water and a dye, and this combination of layered beads, vest and bubble wrap was attached to the front of the water jug, with the layers of beads on the outside. 308 caliber bullets (lead core or soft steel core) were shot at this arrangement from a distance of 10 feet, and failed to penetrate through the vest. The water jug was not broken, indicating that the bullet would have caused minor, if any, blunt trauma injury.

Example 3a

[0062] 4.5 mm round steel copper-coated beads were arranged in 8 layers by laminating the layers of beads together. A layer of ping pong balls (diameter 40 mm) was arranged between two layers of bubble wrap and placed within a sealed ziploc bag. The layers of beads were placed over an RCMP KEVLAR® vest comprising 22 layers of KEVLAR® and the ping pong balls were positioned behind it. This combination was placed in front of a 10 L plastic water jug that was filled with water, with the layers of beads on the outside. A raw egg was positioned between the back of the water jug and a solid barrier. 308 caliber bullets were shot at this arrangement from a distance of 1 meter, and failed to penetrate through the vest. The water jug and the egg were not broken, indicating that the bullets would have caused minor, if any, blunt trauma injury. The ping pong balls were not deformed at all.

Example 3b

[0063] 4.5 mm round steel copper coated beads were arranged in 8 layers by laminating the layers of beads together. A layer of ping pong balls (diameter 40 mm) was arranged between two layers of duct tape. The layers of beads were placed over an RCMP KEVLAR® vest comprising 22 layers of KEVLAR® and the ping pong balls behind it. This combination was placed in front of a 10 L plastic water jug that was filled with water with the layers of beads on the outside. A raw egg was positioned between the back of the water jug and a solid barrier. 308 caliber bullets were shot at this arrangement from a distance of 1 meter, and failed to penetrate through the vest. The water jug and the egg were not broken, indicating that the bullets would have caused minor, if any, blunt trauma injury. However, the ping pong balls were severely deformed as a result of the bullet impact, compared to the ping pong balls in Example 3a, indicating that there would be more energy transfer to the body using this arrangement as compared to the arrangement of Example 3b. Further, the arrangement of Example 3a would be capable of sustaining more hits, than the arrangement of Example 3b.

1. A flexible armour comprising an inner and an outer component:

a) the outer component comprising at least two layers of hard solid beads confined between at least two layers of flexible high impact cloth, and

b) the inner pneumatic component comprising a compartment that is an airtight compartment and/or that is an inflatable compartment.

2. The armour of claim **1** wherein the compartment is confined between at least two layers of flexible high impact cloth.

3. The armour of claim **1** further comprising one or more layers of flexible high-impact cloth disposed between the outer component and the inner component, disposed on an outer surface of the outer component, or disposed on an inner surface of the inner component.

4. The armour of claim **3** wherein the flexible high-impact cloth is KEVLAR and/or SPECTRA.

5. The armour of claim **1** wherein the compartment is an airtight compartment and the airtight compartment is filled with air or gas.

6. The armour of claim **1** wherein the compartment is inflatable and wherein the armour further comprises a sensor that detects a bullet or other projectile before it contacts the armour, and that triggers inflation of the compartment with air or gas before the bullet or other projectile contacts the armour.

7. The armour of claim **1**, wherein the at least two layers of beads in the outer component are made of carbon fiber, aluminum, polycarbon or ceramic, optionally coated with carbon nanotubes.

8. The armour of claim **1**, wherein the at least two layers of beads in the outer component are made of SPECTRA or ALON, optionally coated with carbon nanotubes.

9. The armour of claim **3**, wherein the at least two layers of beads in the outer component are made of carbon fiber, aluminum, polycarbon or ceramic, optionally coated with carbon nanotubes.

10. The armour of claim **3**, wherein the at least two layers of beads in the outer component are made of SPECTRA or ALON, optionally coated with carbon nanotubes.

11. The armour of claim **5**, wherein the at least two layers of beads in the outer component are made of carbon fiber, aluminum, polycarbon or ceramic, optionally coated with carbon nanotubes.

12. The armour of claim **6**, wherein the at least two layers of beads in the outer component are made of carbon fiber, aluminum, polycarbon or ceramic optionally coated with carbon nanotubes.

13. The armour of claim **1** wherein the at least two layers of beads in the outer component are separated from each other by at least one separating layer comprised of a flexible high-impact cloth optionally coated with carbon nanotubes.

14. The armour of claim **3** wherein the at least two layers of beads in the outer component are separated from each other by at least one separating layer comprised of a high-impact cloth.

15. The armour of claim **5** wherein the at least two layers of beads in the outer component are separated from each other by at least one separating layer comprised of a high-impact cloth.

16. The armour of claim **6** wherein the at least two layers of beads in the outer component are separated from each other by at least one separating layer comprised of a high-impact cloth.

17. The armour of claim **1** wherein the compartment comprises at least two subcompartments.

18. The armour of claim **3** wherein the compartment comprises at least two subcompartments.

19. The armour of claim **17** wherein the at least two subcompartments are formed by hollow spheres disposed within the compartment.

20. The armour of claim **17** wherein the at least two subcompartments are formed by a layer of airtight high-impact cloth disposed within the compartment.

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