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(71) Applicant: TENSAR CORPORATION, LLC [US/US]; 2500 Northwinds Parkway, Suite 500, Alpharetta, Georgia 30009 (US).

(72) Inventors: SHELTON, William Stanley; 3526 Fox Hound Run, Lithonia, Georgia 30038-1600 (US). TYAGI, Manoj Kumar; 216 Otter Circle, Fayetteville, Georgia 30215 (US).

(74) Agent: JACOBSON, JR., Harvey B.; Jacobson Holman PLLC, 400 Seventh Street, N.W., Suite 700, Washington, District of Columbia 20004 (US).

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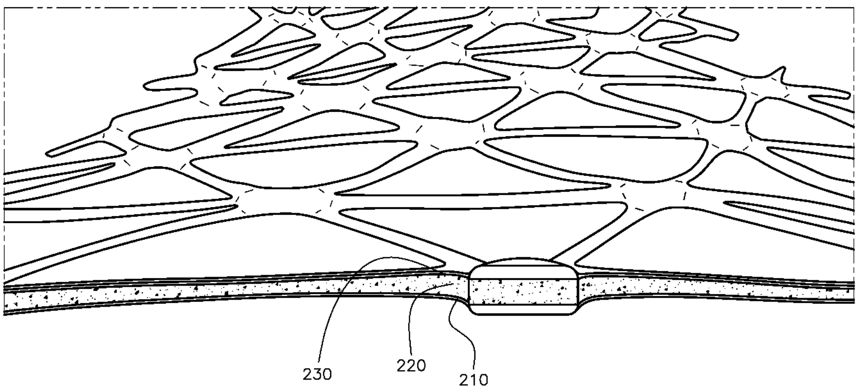

FIG. 7

(57) Abstract: An integral geogrid includes a plurality of interconnected, oriented strands having an array of openings therein that is produced from a coextruded multilayer polymer sheet starting material. By virtue of the construction, the coextruded multilayer sheet components provide a crystalline synergistic effect during extrusion and orientation of the integral geogrid, resulting in enhanced material properties that provide performance benefits to use of the integral geogrid in soil geosynthetic reinforcement.

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GEOGRID MADE FROM A COEXTRUDED MULTILAYERED POLYMER

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of priority to U.S. Provisional Application for Patent No. 62/239,416 filed October 9, 2015.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to integral geogrids and other oriented grids used for structural or construction reinforcement and other geotechnical purposes. More particularly, the present invention relates to such integral geogrids made from a coextruded multilayer polymer sheet in order to achieve enhanced stiffness characteristics, as well as other desirable characteristics as disclosed herein.

This invention also relates to the method of producing such integral geogrids. Lastly, the present invention relates to the use of such integral geogrids for soil and particulate reinforcement and methods of such reinforcement.

For the purpose of this invention, the term “integral geogrid” is intended to include integral geogrids and other integral grid structures made by orienting (stretching) a polymeric starting material in the form of a sheet or a sheet-like shape of a requisite thickness and having holes or depressions made or formed therein.

2. Description of the Prior Art

Polymeric integral grid structures having mesh openings defined by various geometric patterns of substantially parallel, orientated strands and junctions therebetween, such as integral geogrids, have been manufactured for over 25 years. Such grids are manufactured by extruding an integrally cast sheet which is subjected to a defined pattern of holes or depressions followed by the controlled uniaxial or biaxial stretching and orientation of the sheet into highly oriented strands and partially oriented junctions defined by mesh openings formed by the holes or depressions. Such stretching and orienting of the sheet in either uniaxial or biaxial directions develops strand tensile strength and modulus in the corresponding stretch direction. These integral oriented polymer grid structures can be used for retaining or stabilizing particulate material of any suitable form, such as soil, earth, sand, clay, gravel, etc. and in any suitable location, such as on the side of a road or other cutting or embankment, beneath a road surface, runway surface, etc.

Various shapes and patterns of holes have been experimented with to achieve higher levels of strength to weight ratio, or to achieve faster processing speeds during the manufacturing process. Orientation is accomplished under controlled temperatures and strain rates. Some of the variables in this process include draw ratio, molecular weight, molecular weight distribution, and degree of branching or cross linking of the polymer.

The manufacture and use of such integral geogrids and other integral grid structures can be accomplished by well-known techniques. As described in detail in U.S. Patents Nos. 4,374,798 to Mercer, 4,590,029 to Mercer, 4,743,486 to Mercer and Martin, 4,756,946 to Mercer, and 5,419,659 to Mercer, a starting polymeric sheet material is first extruded and then punched to form the requisite defined pattern of holes or depressions. The integral geogrid is then formed by the requisite stretching and orienting the punched sheet material

Such integral geogrids, both uniaxial integral geogrids and biaxial integral geogrids (collectively "integral geogrids," or separately "uniaxial integral geogrid(s)" or "biaxial integral geogrid(s)") were invented by the aforementioned Mercer in the late 1970s and have been a tremendous commercial success over the past 30 years, totally revolutionizing the technology of reinforcing soils, roadway underpavements and other civil engineering structures made from granular or particulate materials.

Mercer discovered that by starting with a relatively thick, substantially uniplanar polymer starting sheet, preferably on the order of 1.5 mm (0.059055 inch) to 4.0 mm (0.15748 inch) thick, having a pattern of holes or depressions whose centers lie on a notional substantially square or rectangular grid of rows and columns, and stretching the starting sheet either unilaterally or biaxially so that the orientation of the strands extends into the junctions, a totally new substantially uniplanar integral geogrid could be formed. As described by Mercer, "uniplanar" means that all zones of the sheet-like material are symmetrical about the median plane of the sheet-like material.

In U.S. Patents Nos. 3,252,181, 3,317,951, 3,496,965, 4,470,942, 4,808,358 and 5,053,264, the starting material with the requisite pattern of holes or depressions is formed in conjunction with a cylindrical polymer extrusion and substantial uniplanarity is achieved by passing the extrusion over an expanding mandrel. The expanded cylinder is then slit longitudinally to produce a flat substantially uniplanar starting sheet.

Another integral geogrid is described in U.S. Patent No. 7,001,112 to Walsh (hereinafter the “Walsh ’112 patent”), assigned to Tensar international Limited, an associated company of the assignee of the instant application for patent, Tensar International Corporation, Inc. (hereinafter “Tensar”) of Atlanta, Georgia. The Walsh ’112 patent discloses oriented polymer integral geogrids including a biaxially stretched integral geogrid in which oriented strands form triangular mesh openings with a partially oriented junction at each corner, and with six highly oriented strands meeting at each junction (hereinafter sometimes referred to herein as “triaxial integral geogrid”).

It is intended that the present invention be applicable to all integral grids regardless of the method of starting sheet formation or of the method of orienting the starting material into the integral geogrid or grid structure.

The subject matter of the foregoing patents Nos. 3,252,181, 3,317,951, 3,496,965, 4,470,942, 4,808,358, 5,053,264 and 7,001,112 is expressly incorporated into this specification by reference as if the disclosures were set forth herein in their entireties. These patents are cited as illustrative, and are not considered to be inclusive, or to exclude other techniques known in the art for the production of integral polymer grid materials.

Traditionally, the polymeric materials used in the production of integral geogrids have been high molecular weight homopolymer or copolymer polypropylene, and high density, high molecular weight polyethylene. Various additives, such as ultraviolet light inhibitors, carbon black, processing aids, etc., are added to these polymers to achieve desired effects in the finished product and/or manufacturing efficiency.

And, also traditionally, the starting material for production of such an integral geogrid has typically been a uniplanar sheet that has a monolayer construction, i.e., a homogeneous single layer of a polymeric material.

While an integral geogrid produced from the above-described conventional starting materials exhibits generally satisfactory properties, it is structurally and economically advantageous to produce an integral geogrid having a relatively higher degree of stiffness suitable for the demands of services such as geosynthetic reinforcement or having other properties desirable for particular geosynthetic applications.

Therefore, a need exists for a starting material not only that is suitable for the process constraints associated with the production of integral geogrids, but also that once the integral geogrid has been produced and is in service, provides a higher degree of stiffness than that associated with conventional geogrid starting materials or provides other desirable properties not available with current monolayer integral geogrids.

SUMMARY OF THE INVENTION

To attain the aforementioned higher degree of stiffness and other desirable characteristics, the present invention employs a coextruded multilayer polymer sheet as the starting material for the fabrication of the integral geogrid.

The experiments described herein support the inventors' theory that by virtue of the inventive construction, the coextruded multilayer sheet components provide a crystalline synergistic effect during extrusion and orientation, resulting in enhanced material properties that provide performance benefits to use of the integral geogrid in soil geosynthetic reinforcement.

According to one embodiment of the present invention, a starting material for making an integral geogrid includes a coextruded multilayer polymer sheet having holes or depressions therein that provide openings when the starting material is uniaxially or biaxially stretched.

According to another embodiment of the present invention, an integral geogrid includes a plurality of highly oriented strands interconnected by partially oriented junctions and having an array of openings therein that is produced from a coextruded multilayer polymer sheet. According to one embodiment of the invention, the integral geogrid is a triaxial integral geogrid.

According to still another embodiment of the present invention, a soil construction includes a mass of particulate material strengthened by embedding therein an integral geogrid produced from a coextruded multilayer polymer sheet.

According to yet another embodiment of the present invention, a method of making a starting material for an integral geogrid includes providing a coextruded multilayer polymer sheet, and providing holes or depressions therein.

According to another embodiment of the present invention, a method of making an integral geogrid includes providing a coextruded multilayer polymer sheet, providing holes or depressions therein, and uniaxially or biaxially stretching the coextruded multilayer polymer sheet having the holes or depressions therein so as to provide a plurality of highly oriented strands interconnected by partially oriented junctions and having an array of the openings therein. According to one embodiment of the invention, the method produces a triaxial integral geogrid from a coextruded multilayer polymer sheet.

And, according to yet another embodiment of the present invention, a method of strengthening a mass of particulate material includes embedding in the mass of particulate material an integral geogrid produced from a coextruded multilayer polymer sheet.

Accordingly, it is an object of the present invention to provide a starting material for making an integral geogrid. The starting material includes a coextruded multilayer polymer sheet having holes or depressions therein that provide openings when the starting material is uniaxially or biaxially stretched.

Another object of the present invention is to provide an integral geogrid having a plurality of highly oriented strands interconnected by partially oriented junctions and having an array of openings therein that is produced from a coextruded multilayer polymer sheet. An associated object of the invention is to provide an integral geogrid characterized by a higher degree of stiffness, a greater strength, and other desirable characteristics. Specifically, an object of the present invention is to provide a triaxial integral geogrid from a coextruded multilayer polymer sheet.

Still another object of the present invention is to provide a soil construction that includes a mass of particulate material strengthened by embedding therein an integral geogrid produced from a coextruded multilayer polymer sheet.

Yet another object of the present invention is to provide a method of making a starting material for an integral geogrid that includes providing a coextruded multilayer polymer sheet, and providing holes or depressions therein.

Another object of the present invention is to provide a method of making an integral geogrid. The method includes providing a coextruded multilayer polymer sheet, providing holes or depressions therein, and uniaxially or biaxially stretching the coextruded multilayer polymer sheet having the holes or depressions therein so as to provide a plurality of highly oriented strands interconnected by partially oriented junctions and having an array of the openings therein. The method can employ known geogrid fabrication methods, such as those described in the aforementioned U.S. Patent Nos. 4,374,798, 4,590,029, 4,743,486, 5,419,659, and 7,001,112, as well as in other patents. Specifically, an object of the present invention is to provide a method of making a triaxial integral geogrid from a coextruded multilayer polymer sheet.

And, still another object of the present invention is to provide a method of strengthening a mass of particulate material by embedding in the mass of particulate material an integral geogrid produced from a coextruded multilayer polymer sheet.

These together with other objects and advantages which will become subsequently apparent reside in the details of construction and operation as more fully hereinafter described, reference being had to the accompanying drawings forming a part hereof, wherein like reference numbers refer to like parts throughout. The accompanying drawings are intended to illustrate the invention, but are not necessarily to scale.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates a coextruded uniplanar multilayer sheet starting material for an integral geogrid, before holes or depressions are formed therein according to one embodiment of the present invention.

Figure 2 is a perspective plan view of the starting material sheet shown in Figure 1 that has the holes punched therein for forming a triaxial integral geogrid of the type shown in the Walsh ’112 patent.

Figure 3 is a side view of a section of the starting material sheet shown in Figure 2.

Figure 4 is a plan view of a section of the triaxial integral geogrid produced by biaxially orienting the starting material sheet shown in Figure 2.

Figure 5 is a perspective view of the section of the triaxial integral geogrid shown in Figure 4.

Figure 6 is an enlarged perspective view of the section of the triaxial integral geogrid shown in Figure 4.

Figure 7 is a side cross-sectional view of the section of the triaxial integral geogrid shown in Figure 4.

Figure 8 is a table summarizing aperture stability modulus properties for an experimental triaxial integral geogrid produced from a 3 mm coextruded uniplanar multilayer sheet starting material such as shown in Figures 1-7 to be compared with similar properties of a triaxial integral geogrid commercially available from Tensar as a TriAx® TX140™ geogrid.

Figure 9 is a table comparing various product properties of triaxial integral geogrids commercially available from Tensar (produced from extruded monolayer sheets) with corresponding various product properties of experimental triaxial integral geogrids as shown in Figures 4-7 produced from coextruded uniplanar multilayer sheets according to the present invention.

Figure 10 is another table comparing various product properties of triaxial integral geogrids commercially available from Tensar (produced from extruded monolayer sheets) with corresponding product properties of experimental triaxial integral geogrids produced from coextruded uniplanar multilayer sheets according to the present invention.

Figure 11 is a perspective view of a section of a triaxial integral geogrid according to another embodiment of the present invention.

Figure 12 is a plan view of the section of the triaxial integral geogrid shown in Figure 11.

Figure 13 is a side cross-sectional view of the section of the triaxial integral geogrid shown in Figure 11.

Figure 14 illustrates a coextruded uniplanar multilayer sheet starting material for an integral geogrid, before holes or depressions are formed therein according to another embodiment of the present invention.

Figure 15 is a perspective view of a section of a triaxial integral geogrid associated with the starting material sheet shown in Figure 14.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Although only preferred embodiments of the invention are explained in detail, it is to be understood that the invention is not limited in its scope to the details of construction and arrangement of components set forth in the following description or illustrated in the drawings. The invention is capable of other embodiments and of being practiced or carried out in various ways.

Also, in describing the preferred embodiments, terminology will be resorted to for the sake of clarity. It is intended that each term contemplates its broadest meaning as understood by those skilled in the art, and includes all technical equivalents which operate in a similar manner to accomplish a similar purpose.

And, as used herein, the terms “coextruded,” “coextruding,” and “coextrusion” are used according to their commonly accepted definition, i.e., pertaining to a single-step process starting with two or more polymeric materials that are simultaneously extruded and shaped in a single die to form a multilayer sheet.

The present invention is directed to uniaxial, biaxial, and triaxial integral geogrid structures produced from a coextruded multilayer polymer sheet as the starting material. The coextruded multilayer polymer sheet starting material can be, for example, uniplanar, or can be non-uniplanar, depending upon the particular characteristics that are desired for the multilayer geogrid structure that is to be fabricated therefrom. According to a preferred embodiment of the invention, the coextruded multilayer polymer sheet starting material is uniplanar or substantially uniplanar.

The invention is based on the fact that extrusion of the coextruded multilayer sheet consisting of different polymeric materials or other extrudable materials at varying percentage content when converted to uniaxial, biaxial, and/or triaxial integral geogrids via a sheet punching and oven stretching process, produces a finished product that has unique characteristics relative to the traditional uniaxial, biaxial, and triaxial geogrids for purposes of soil reinforcement and other geotechnical applications.

Figure 1 illustrates a coextruded multilayer sheet 100 used as a starting material for an integral geogrid according to one embodiment of the present invention, before the sheet has been through-punched or depressions formed therein.

As shown in Figure 1, the coextruded multilayer sheet 100 is a three-layer sheet embodiment of the invention. That is, preferably, sheet 100 includes a first layer 110, a second layer 120, and a third layer 130. The first layer 110 and the third layer 130 are arranged on opposite planar surfaces of second layer 120, preferably in a uniplanar or substantially uniplanar configuration. Further, while the three-layer configuration of sheet 100 is shown for purposes of illustration, the invention contemplates the use of a sheet having multiple layers arranged in various configurations, multiple layers having various combinations of thicknesses, and multiple layers having various materials of construction, all as dictated by the particular application in which the integral geogrid is to be employed. For example, while the three-layer configuration of sheet 100 is shown for purposes of illustration, the invention also contemplates the use of coextruded sheets having more than three layers. In general, the layer configuration, the layer thicknesses, and the materials of construction of the layers are selected to provide not only ease of fabrication of the integral geogrid, but also an integral geogrid having the desired degree of stiffness and other performance properties.

As described above, the coextruded multilayer sheet 100 used as the starting material for an integral geogrid according to the present invention is preferably through-punched, although it may be possible to use depressions formed therein instead. According to the embodiment of the starting material in which depressions are formed in the sheet, the depressions are provided on each side of the sheet, i.e., on both the top and the bottom of the sheet. Further, the depressions extend into each layer of the coextruded multilayer sheet.

In the particular embodiment of the invention shown in Figure 1, the sheet 100 is made by coextruding a first material that forms the first layer 110, a second material that forms the second layer 120, and a third material that forms the third layer 130 in a manner known to those skilled in the art of extruding multi-layer sheets.

According to a preferred embodiment of the invention, the overall thickness of the sheet 100 is from about 2 mm to about 12 mm and, according to a more preferred embodiment of the invention, the overall thickness of the sheet 100 is from about 2 mm to about 6 mm.

With regard to the individual thicknesses of the sheet layers, according to a preferred embodiment of the invention, the thickness of the first layer 110 is from about 0.5 mm to about 4.5 mm, the thickness of the second layer 120 is from about 1 mm to about 9 mm, and the thickness of the third layer 130 is from about 0.5 mm to about 4.5 mm, keeping in mind that the overall thickness of the sheet 100 is from about 2 mm to about 12 mm. And, according to a more preferred embodiment of the invention, the thickness of the first layer 110 is from about 0.5 mm to about 2 mm, the thickness of the second layer 120 is from about 2 mm to about 5 mm, and the thickness of the third layer 130 is from about 0.5 mm to about 2 mm.

In general, the material of construction of the first layer 110, the second layer 120, and the third layer 130 may be the same as each other, or may be different from one another. Preferably, the material of construction of the first layer 110 and the material of construction of the third layer 130 may be the same as each other, or may be different from one another. More preferably, material of construction of the second layer 120 is different from the material of construction of both the first layer 110 and the material of construction of the third layer 130.

And, in general, the layers of the sheet are polymeric in nature. For example, the materials of construction may include high molecular weight polyolefins, and broad specification polymers. Further, the polymeric materials may be virgin stock, or may be recycled materials, such as, for example, post-industrial or post-consumer recycled polymeric materials. And, the use of one or more polymeric layers having a lower cost than that of the aforementioned high molecular weight polyolefins and broad specification polymers is also contemplated. The use of such a lower cost polymeric layer may result in a cost savings of approximately 20% to approximately 30% relative to the use of, for example, a polypropylene layer.

According to a preferred embodiment of the invention, the material of construction of the first layer 110 and the third layer 130 is a high molecular weight polyolefin, such as, for example, a polypropylene (“PP”). And, according to the same preferred embodiment, the material of construction of the second layer 120 is a broad specification polymer, such as, for example, a virgin PP, or a recycled PP, such as, for example, a post-industrial PP or other recycled PP. However, depending upon the particular application of the integral geogrid, polymeric components having a material of construction other than polypropylene may be included in the coextruded multilayer sheet.

Figures 2 and 3 illustrate the coextruded multilayer sheet starting material 100 of Figure 1 that has holes 140 punched therein for forming the triaxial integral geogrid 200 shown in Figures 4, 5, and 6. The size and spacing of the holes 140 are as disclosed in the Walsh ’112 patent. The triaxial integral geogrid 200 includes highly oriented strands 205 and partially oriented junctions 235, also as disclosed in the Walsh ’112 patent. The upper layer 130 of the starting material 100 has been stretched and oriented into the upper layer 230 of the strands 205 and junctions 235. Similarly, the third or lower layer 110 of the starting material 100 has been stretched and oriented into the lower or underneath layer 210 of the strands 205 and junctions 235. As the first layer 130 and third layer 110 are being stretched and oriented, the second or middle layer 120 is also being stretched and oriented into middle layer 220 of both the strands 205 and junctions 235.

The invention also relates to a method of making the above-described triaxial integral geogrid 200. The method includes: providing the coextruded multilayer polymer sheet 100; forming a plurality of holes or depressions in the coextruded multilayer polymer sheet 100 in a selected pattern, such as in accordance with the disclosure of the Walsh ’112 patent; and biaxially stretching and orienting the coextruded multilayer polymer sheet having the patterned plurality of holes or depressions therein to form an integral geogrid having a plurality of interconnected, oriented strands between partially oriented junctions and to configure the holes or depressions as grid openings.

In general, once the coextruded multilayer polymer sheet 100 has been prepared with holes or depressions, the triaxial integral geogrid 200 can be produced from the sheet

100 according to the methods described in the above-identified patents and known to those skilled in the art.

To demonstrate the enhanced characteristics and properties of the inventive integral geogrid produced from the coextruded multilayer sheet, comparative tests were performed.

Figure 8 is a table summarizing aperture stability modulus properties for an experimental triaxial integral geogrid produced from a 3 mm coextruded sheet starting material to be compared with similar properties of a triaxial integral geogrid commercially available from Tensar as a TriAx® TX140™ geogrid. The experiment was performed according to the testing protocols of ASTM D7864, i.e., the "Standard Test Method for Determining the Aperture Stability Modulus of Geogrids." The aperture stability testing was performed on triaxial integral geogrid samples made from a 3 mm thick coextruded multilayer sheet that included a 50% BSR ("broad specification resin") that had been punched and stretched. The first, i.e., lower, layer 110 of the coextruded multilayer sheet had a material of construction of a high molecular weight polypropylene (PP) and a thickness of 0.75 mm; the second, i.e., middle, layer 120 had a material of construction of a broad specification PP and a thickness of 1.50 mm; and the third, i.e., upper, layer 130 had a material of construction of a high molecular weight PP and a thickness of 0.75 mm.

For the experimental laboratory-prepared triaxial integral geogrid made from the coextruded multilayer sheet, the average value for a moment of 20 cm-kg was 3.70 cm-kg/deg. Conversely, for the non-coextruded, i.e., monolayer sheet, specifically from six tests of the standard Triax® TX140™ geogrids, the average value of the tests was 2.86 cm-kg/deg, with a range of 2.52 to 3.14 cm-kg/deg, substantially below the average value recorded for the experimental multilayer samples.

Figure 9 also illustrates various product properties of triaxial integral geogrids produced from monolayer extruded sheets with corresponding product properties of triaxial integral geogrids produced from coextruded multilayer sheets according to the present invention. In the tests summarized in Figure 9, the monolayer sheets were processed to have the configuration of the triaxial integral geogrid described in the Walsh '112 patent. Such a triaxial integral geogrid is commercially available from Tensar, and is known as the TriAx® TX160™ geogrid.

For the comparative experiments shown in Figure 9, coextruded 3-layer sheets in 4.6 mm finished sheet thicknesses were prepared. The various sheets incorporated different loadings of post-industrial polypropylene (PP) content, and each of the coextruded 3-layer sheets was then processed into a triaxial integral geogrid comparable to Tensar's TriAx® TX160™ geogrid.

With regard to Figure 9, each of the 4.6 mm coextruded multilayer sheets included the following layer compositions: Sample (1) a first or upper layer 130, as described above, of 34% virgin polypropylene (PP) and black masterbatch ("MB," i.e., black carbon to provide a black color to the product for UV protection) / a second or middle layer 120, as described above, of 32% post-industrial PP / and a third or lower layer 110, as described above, of 34% virgin PP and MB; and Sample (2) 25% virgin PP and MB / 50% post-industrial PP / 25% virgin PP and MB.

The thickness of each of the above-described layers for the various sheet Samples (1) and (2) is as follows. For the 4.6 mm multilayer sheet Sample (1), the thicknesses of the layers were, respectively: 1.56 mm / 1.47 mm / 1.56 mm. For the 4.6 mm multilayer sheet Sample (2), the thicknesses of the layers were, respectively: 1.15 mm / 2.30 mm / 1.15 mm.

As is evident from the results presented in Figure 9, the resultant experimental triaxial integral geogrids produced from the above-described punched and oriented 4.6 mm coextruded 3-layer sheet samples resulted in a product, versus the standard monolayered Triax® TX160™ geogrid with the approximate equivalent starting sheet thickness (4.7 mm), that exhibited substantially higher product stiffness as measured per standard Tensar low strain tensile modulus testing, flexural stiffness testing, and aperture stability testing. The 0.5% and 2.0% strain tensile modulus test values were more than 30% stronger for the experimental triaxial geogrids produced from the 4.6 mm coextruded 3-layer starting sheet than from the conventional Triax® TX160™ geogrids produced from the 4.7 mm monolayered sheet. Similarly, the flexural stiffness measured more than 33% higher for the experimental triaxial geogrids produced from the 4.6 mm coextruded sheet than the standard Triax® TX160™ geogrid made from a 4.7 mm monolayered starting sheet.

Figure 10 is another table comparing various product properties of triaxial integral geogrids produced from monolayer sheets commercially available from Tensar with corresponding product properties of experimental triaxial integral geogrids produced from coextruded multilayer sheets according to the present invention. In the tests summarized in Figure 10, the monolayer sheets were also processed to have the configuration of the triaxial integral geogrid described in the Walsh ‘112 patent. Such a triaxial integral geogrid is commercially available from Tensar, and is known as the TriAx® TX140™ geogrid.

For the comparative experiments shown in Figure 10, coextruded 3-layer sheets in 3.0 mm finished sheet thicknesses were prepared. The various sheets incorporated different loadings of post-industrial polypropylene (PP) content, and each of the coextruded 3-layer sheets was then processed into a triaxial integral geogrid comparable to Tensar's TriAx® TX140™ geogrid.

With regard to Figure 10, Sheet "SN20140407" had the following composition: 32% broad specification resin in the second (i.e., middle) layer 120 and 34% high molecular weight PP in the first (i.e. top) layer 130 and in the third (i.e., lower) layer 110. Sheet "SN20140408" had the following composition: 50% broad specification resin in the second (i.e., middle) layer, and 25% high molecular weight PP in the first layer and in the third layer. Sheet "SN20140409" had the following composition: 60% broad specification resin in the second (i.e., middle) layer, and 20% high molecular weight PP in the first layer and in the third layer.

The thickness of each of the above-described layers for Sheet SN20140407, Sheet SN20140408, and Sheet SN20140409 is as follows. For the 3 mm multilayer Sheet SN20140407, the thicknesses of the first, the second, and the third layers were, respectively: 1.02 mm / 0.96 mm / 1.02 mm. For the 3 mm multilayer Sheet SN20140408, the thicknesses of the layers were, respectively: 0.75 mm / 1.5 mm / 0.75 mm. For the 3 mm multilayer Sheet SN20140409, the thicknesses of the layers were, respectively: 0.6 mm / 1.8 mm / 0.6 mm.

As is evident from the results reported in Figure 10, the 3.0 mm starting sheet thickness with post-industrial PP content of 32% (SN20140407), 50% (SN20140408), and 60% (SN20140409), when converted to a finished triaxial integral geogrid, exceeded the only specified tensile modulus test for Triax® TX140™ geogrid produced from a 3.7 mm thick sheet which is 220 kN/m in the transverse direction (“TD”). Figure 10 also shows that each of the coextruded samples, starting with the thinner 3.0 mm sheet, met or exceeded the average tensile modulus values of standard Triax® TX140™ geogrid produced from a 3.7 mm sheet.

Again, the experiments described herein support the inventors’ concept that by virtue of utilizing a multi-layer construction for the starting material sheet, the coextruded multilayer sheet components can provide a crystalline synergistic effect during extrusion and orientation, thus providing enhanced material properties in the resultant integral geogrid and performance benefits when using the resultant integral geogrid in soil and other geotechnical applications.

Other possible embodiments of the instant invention can include, for example, (1) multilayer coextruded polymer sheet starting materials having significantly higher levels of post-industrial and post-consumer PP resins, i.e., PP resins that have a relatively low cost, (2) foaming agents to provide a foamed or expanded second (i.e., middle) layer, (3) one or more relatively low cost layers that include bulking agents or fillers, (4) a color identification layer within the integral geogrid, and (5) a 3-layer coextruded polymer sheet with HDPE outer layers and an amorphous and crystalline polyester inner layer sandwiched therebetween. Each of the above examples would provide an enhancement or satisfy a need for an integral geogrid having enhanced geosynthetic aggregate reinforcement, cost reduction and/or identification properties.

More specifically, as indicated above, one possible embodiment of the instant invention could include the use of a foaming agent to provide a foamed or expanded second or middle layer. Figures 11, 12, and 13 are directed to such an embodiment 300, in which the second or middle layer (here designated as 320) of the coextruded multilayer sheet forms an expanded or "foamed" structure. That is, according to this embodiment of the invention, a chemical foaming agent is mixed with the polymer that is extruded to form the second layer. The heat that is generated to melt the polymer decomposes the chemical foaming agent, which results in the liberation of a gas. The gas is then dispersed in the polymer melt, and expands upon exiting the die. As a result, the second layer is expanded or foamed (see Figure 13, which is a side cross-sectional view of the section of the integral triaxial geogrid shown in Figure 11.)

According to this embodiment of the invention, as with the above-described first embodiment, the material of construction of the first layer (here, 310) and the material of construction of the third layer (here, 330) may be the same as each other, or may be different from one another, although the same material is preferred. In general, the material of construction of the second layer 320 is different from the material of construction of both the first layer 310 and the material of construction of the third layer 330.

Advantages of the foamed embodiment of the finished integral geogrid according to the present invention not only include reduced raw material cost and reduced geogrid weight, but also may include desirable physical and chemical properties of the foamed layer *per se*.

As indicated above, one possible embodiment of the instant invention could include the use of a color identification layer with the integral geogrid. For example, the American Association of State Highway and Transportation Officials (“AASHTO”) requires, in conjunction with the National Transportation Product Evaluation Program (“NTPEP”), a product marker for geosynthetic reinforcements associated with walls, slopes, and fills over soft ground.

The above-described color identification layer could be, for example, a polymeric layer having a color that differs from the color of an adjacent, or an associated, co-extruded layer. The color identification layer could be an inner layer or an outer layer of the integral geogrid, or the integral geogrid could include multiple color identification layers of either the same color or a variety of colors. The color identification layer could be a solid color, or could have a pattern, such as incorporating a stripe. The color and/or chemistry of the color identification layer is selected, of course, based upon the requirements of a particular application of the integral geogrid.

In addition to the above-described use of the integral geogrid’s color identification layer for compliance with AASHTO and NTPEP standards, the color identification layer can also serve to provide source identification of the integral geogrid.

As indicated above, while the three-layer configuration of sheet 100 has been shown for purposes of illustration, the invention also contemplates the use of coextruded sheets having more than three layers.

For example, the coextruded sheet can be a five-layer configuration, such as sheet 400 shown in Figure 14. Sheet 400 includes a middle layer 420, a first inner layer 410, a second inner layer 430, a first outer layer 440, and a second outer layer 450. The first inner layer 410 and the second inner layer 430 are arranged on opposite planar surfaces of middle layer 420, preferably in a uniplanar or substantially uniplanar configuration. The first outer layer 440 and the second outer layer 450 are arranged on opposite planar surfaces of, respectively, first inner layer 410 and second inner layer 430, preferably in a uniplanar or substantially uniplanar configuration.

In the particular embodiment of the invention shown in Figure 14, the sheet 400 is made by coextruding a first material that forms the middle layer 420, a second material that forms the first inner layer 410, a third material that forms the second inner layer 430, a fourth material that forms the first outer layer 440, and a fifth material that forms the second outer layer 450, in a manner known to the those skilled in the art of extruding multi-layer sheets.

In general, the material of construction of the middle layer 420, the first inner layer 410, the second inner layer 430, the first outer layer 440, and the second outer layer 450 may be the same as each other, or may be different from one another. For example, the middle layer 420 may have a first material of construction, the first inner layer 410 and the second inner layer 430 may have a second material of construction, and the first outer layer 440 and the second outer layer 450 may have a third material of construction. In summary, depending upon the particular service application in which the integral geogrid made from the sheet 400 is to be employed, various combinations of materials of construction for the above-described five layers may be used.

Figure 15 is a perspective view of a section of a triaxial integral geogrid 500 associated with the starting material sheet 400 shown in Figure 14. The triaxial integral geogrid 500 includes highly oriented strands 505 and partially oriented junctions 535. After holes have been punched in sheet 400, the first outer layer 440 and the second outer layer 450 of sheet 400 have been stretched and oriented into, respectively, the first outer layer 540 and the second outer layer 550 of the strands 505 and junctions 535. Similarly, the first inner layer 410 and the second inner layer 430 of sheet 400 have been stretched and oriented into, respectively, the first inner layer 510 and the second inner layer 530 of the strands 505 and junctions 535. And, as the first outer layer 440 and the second outer layer 450, and the first inner layer 410 and the second inner layer 430 are being stretched and oriented, the middle layer 420 is also being stretched and oriented into middle layer 520 of both the strands 505 and junctions 535.

As also indicated above, one possible embodiment of the instant invention could include the use of one or more relatively low cost layers that include bulking agents or fillers. The inclusion of such bulking agents or fillers in the layers of the integral geogrid create a product having a thicker, i.e., loftier, profile, which can lead to enhanced performance of the integral geogrid in certain service applications. Depending upon the service application in which the integral geogrid is to be employed, such bulking agents or fillers, may include, for example, one or more of $CaCO_3$ (calcium carbonate), talc, $CaSiO_3$ (wollastonite), nano-fillers, multi-wall carbon nanotube (“MWCNT”), single wall carbon nanotube (“SWCNT”), glass fibers, and aluminum hydrate.

As described earlier above, the use of one or more polymeric layers having a lower cost than that of high molecular weight polyolefins and broad specification polymers is contemplated. In an embodiment in which such a lower cost polymeric layer also includes the aforementioned bulking agent or filler, a cost savings of approximately 20% relative to the use of, for example, a polypropylene layer, may result.

And, of course, use of the above-described foam layer can also create a product having a thicker, i.e., loftier, profile, which can also lead to enhanced performance of the integral geogrid in certain service applications. Contemplated embodiments of the invention include those in which one or more of the foamed layers are used in conjunction with one or more layers that include the bulking agents or fillers.

In general, the instant invention is based on employing the coextrusion techniques and materials described herein to modify and enhance certain physical, chemical, and/or mechanical properties of an integral geogrid so as to improve the performance of the integral geogrid in a particular application thereof.

The foregoing is considered as illustrative only of the principles of the invention. Further, since numerous modifications and changes may readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation described and shown.

WHAT IS CLAIMED IS:

1. An integral geogrid comprising a plurality of interconnected, oriented strands having an array of openings therein, the integral geogrid being produced from a coextruded multilayer polymer sheet.

2. The integral geogrid according to claim 1, wherein the oriented strands have been uniaxially or biaxially stretched.

3. The integral geogrid according to claim 1, wherein the coextruded multilayer polymer sheet includes a first layer, a second layer, and a third layer, with the first layer and the third layer being arranged on opposite planar surfaces of the second layer.

4. The integral geogrid according to claim 1, wherein the coextruded multilayer polymer sheet has a thickness of from about 2 mm to about 12 mm.

5. The integral geogrid according to claim 3, wherein the first layer has a thickness of from about 0.5 mm to about 4.5 mm, the second layer has a thickness of from about 1 mm to

about 9 mm, and the third layer has a thickness of from about 0.5 mm to about 4.5 mm.

6. The integral geogrid according to claim 3, wherein the first layer has a material of construction of a high molecular weight polyolefin, the second layer has a material of construction of a broad specification polymer, and the third layer has a material of construction of a high molecular weight polyolefin.

7. The integral geogrid according to claim 6, wherein the high molecular weight polyolefin of the first layer is a polypropylene, the broad specification polymer of the second layer is a post-industrial polypropylene, and the high molecular weight polyolefin of the third layer is a polypropylene.

8. The integral geogrid according to claim 1, wherein the plurality of interconnected, oriented strands includes transverse strands interconnected by substantially longitudinally oriented strands.

9. The integral geogrid according to claim 1, wherein the integral geogrid is configured for structural or construction reinforcement purposes.

10. A starting material for making an integral geogrid comprising a coextruded multilayer polymer sheet having holes or depressions therein that provide openings when the sheet is uniaxially or biaxially stretched.

11. The starting material according to claim 10, wherein the coextruded multilayer polymer sheet includes a first layer, a second layer, and a third layer, with the first layer and the third layer being arranged on opposite planar surfaces of the second layer.

12. The starting material according to claim 10, wherein the coextruded multilayer polymer sheet has an initial thickness of at least 2 mm.

13. The starting material according to claim 10, wherein the coextruded multilayer polymer sheet has a stretched thickness of from about 0.2 mm to about 9 mm.

14. The starting material according to claim 10, wherein the coextruded multilayer polymer sheet once stretched exhibits an increased flexural stiffness and torsional rigidity relative to the flexural stiffness and torsional rigidity of a non-coextruded sheet having a substantially same starting thickness.

15. A soil construction comprising a mass of particulate material strengthened by embedding therein an integral geogrid as claimed in claim 1.

16. A method of strengthening a mass of particulate material, comprising embedding in the mass of particulate material the integral geogrid as claimed in claim 1.

17. A method of making an integral geogrid, comprising:

providing a coextruded multilayer polymer sheet;

providing a patterned plurality of holes or depressions in the coextruded multilayer polymer sheet; and

orienting the coextruded multilayer polymer sheet having the patterned plurality of holes or depressions therein to provide a plurality of interconnected, oriented strands and to configure the holes or depressions as grid openings.

18. The method according to claim 17, wherein the coextruded multilayer polymer sheet having the patterned plurality of holes or depressions therein is oriented by uniaxial or biaxial stretching.

19. The method according to claim 17, wherein the coextruded multilayer polymer sheet includes a first layer, a second layer, and a third layer, with the first layer and the third layer being arranged on opposite planar surfaces of the second layer.

20. The method according to claim 17, wherein the coextruded multilayer polymer sheet has an initial thickness of at least 2 mm.

21. The method according to claim 17, wherein the first layer has a thickness of from about 0.5 mm to about 4.5 mm, the second layer has a thickness of from about 1 mm to about 9 mm, and the third layer has a thickness of from about 0.5 mm to about 4.5 mm.

22. The method according to claim 17, wherein the first layer has a material of construction of a high molecular weight polyolefin, the second layer has a material of construction of

a broad specification polymer, and the third layer has a material of construction of a high molecular weight polyolefin.

23. A method of providing an integral geogrid construction, comprising:

uniaxially or biaxially stretching a starting material that is a coextruded multilayer polymer sheet having a patterned plurality of holes or depressions therein to provide an integral geogrid having a plurality of oriented strands and a plurality of grid openings; and

embedding the integral geogrid in a mass of particulate material.

24. The integral geogrid according to claim 1, wherein the integral geogrid is a triaxial integral geogrid.

25. The method according to claim 17, wherein the integral geogrid is a triaxial integral geogrid.

26. The method according to claim 17, wherein the integral geogrid is a uniaxial integral geogrid.

27. The method according to claim 17, wherein the integral geogrid is a biaxial integral geogrid.

28. The method according to claim 17, wherein the integral geogrid includes a color identification layer.

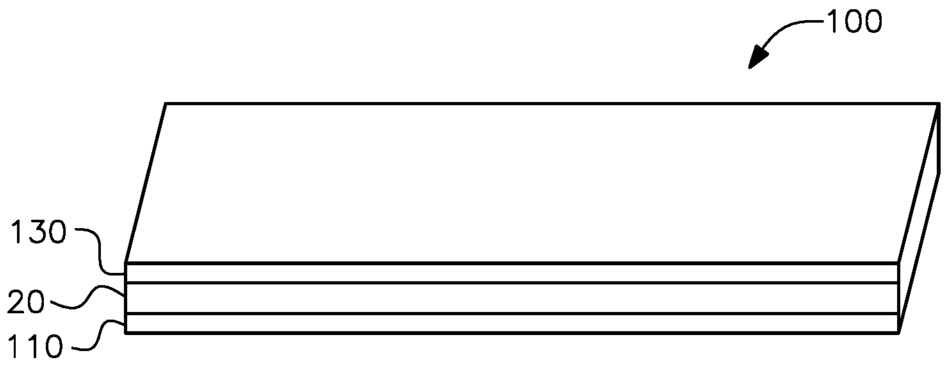

FIG. 1

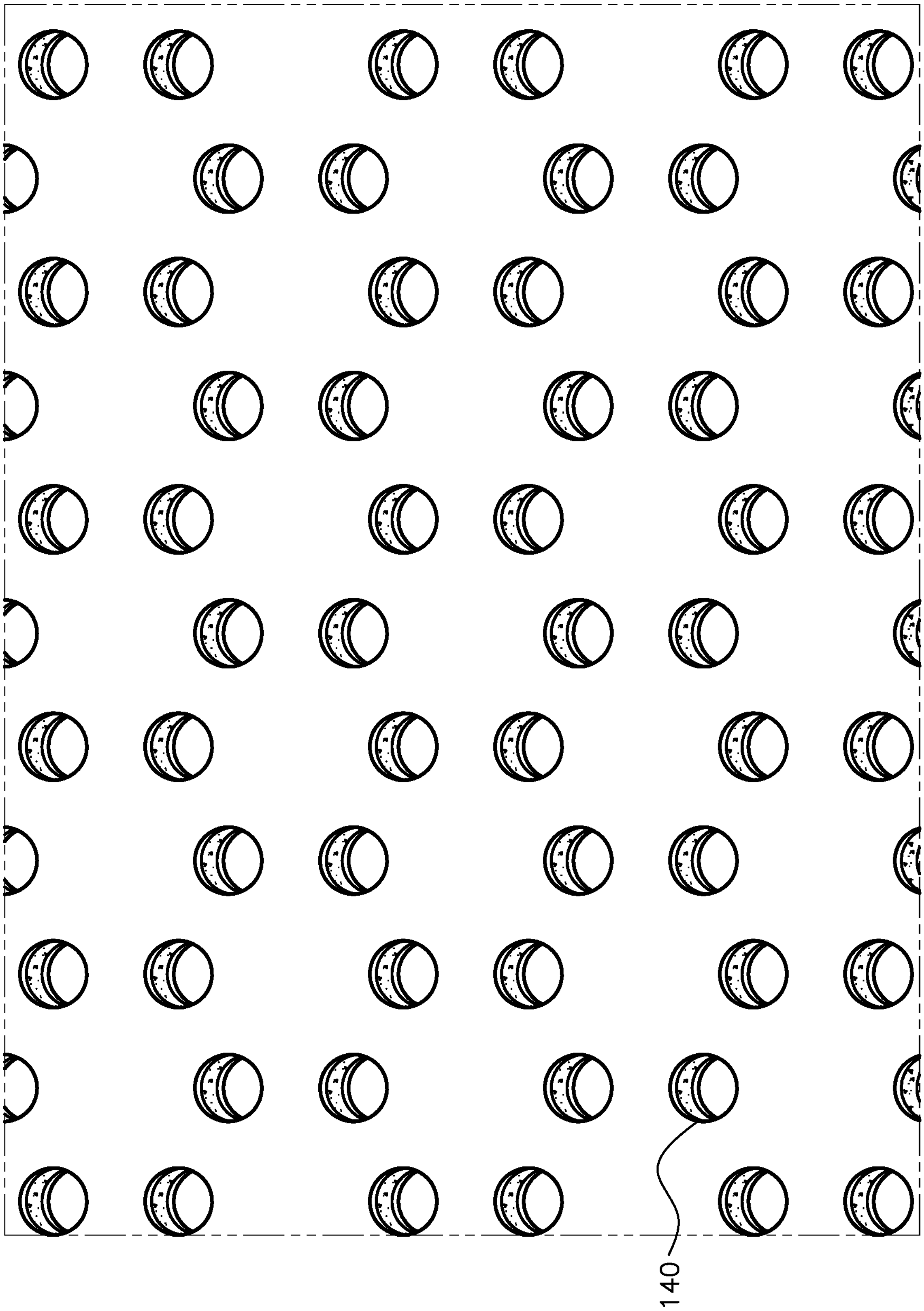

FIG. 2

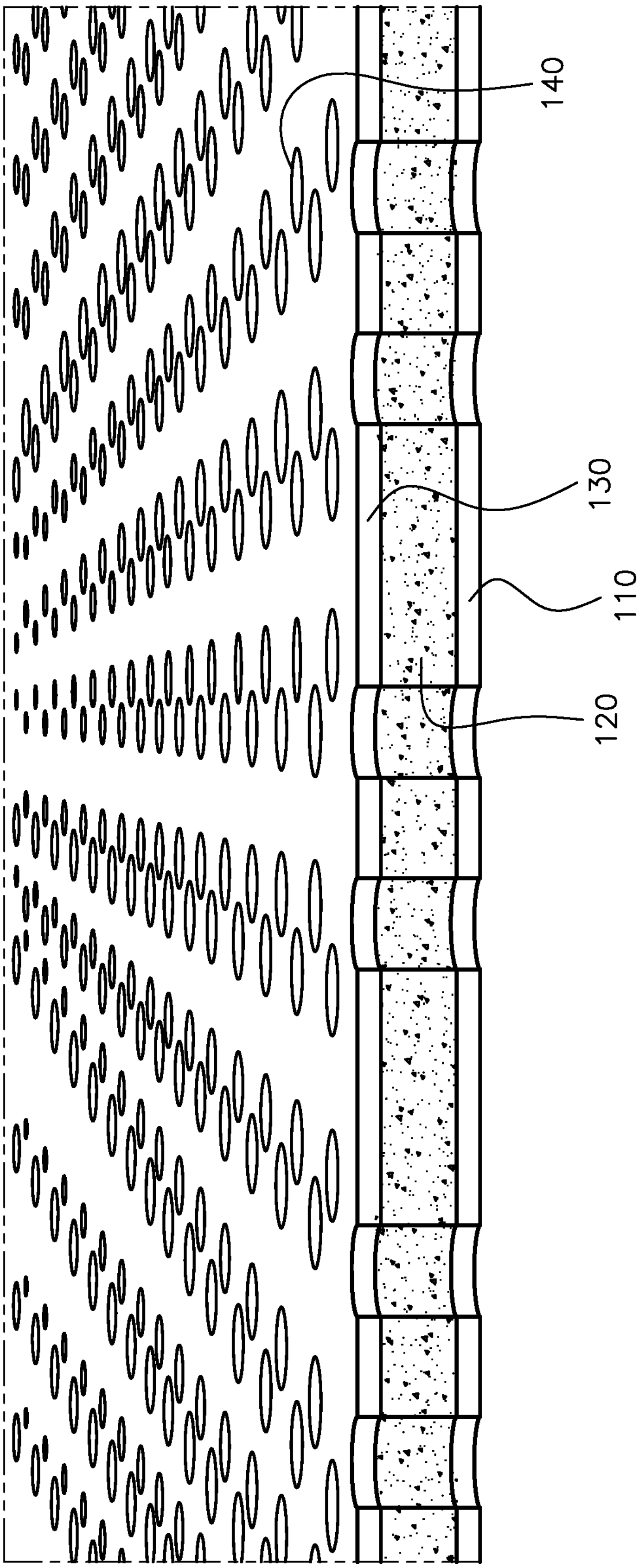

FIG. 3

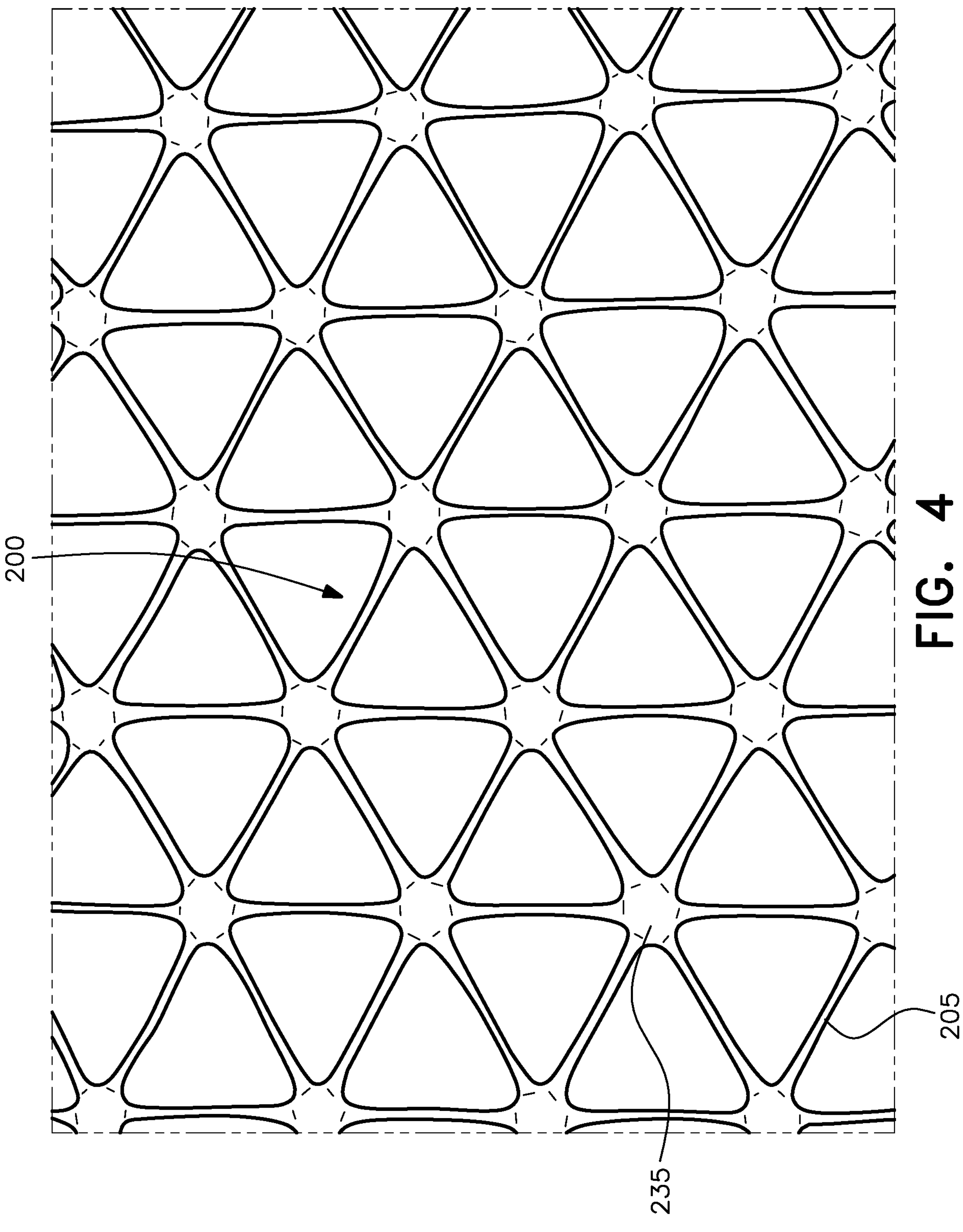

FIG. 4

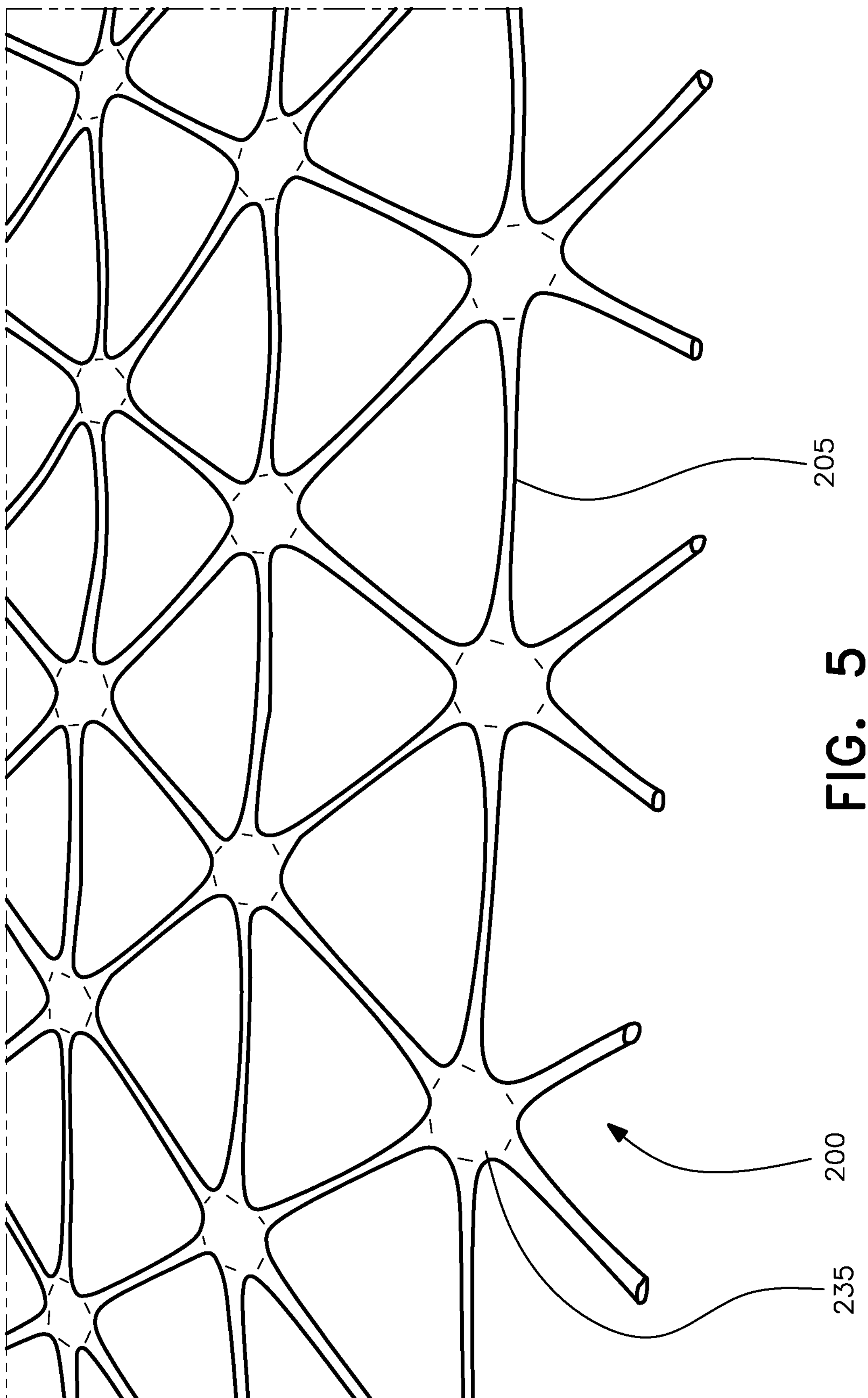

FIG. 5

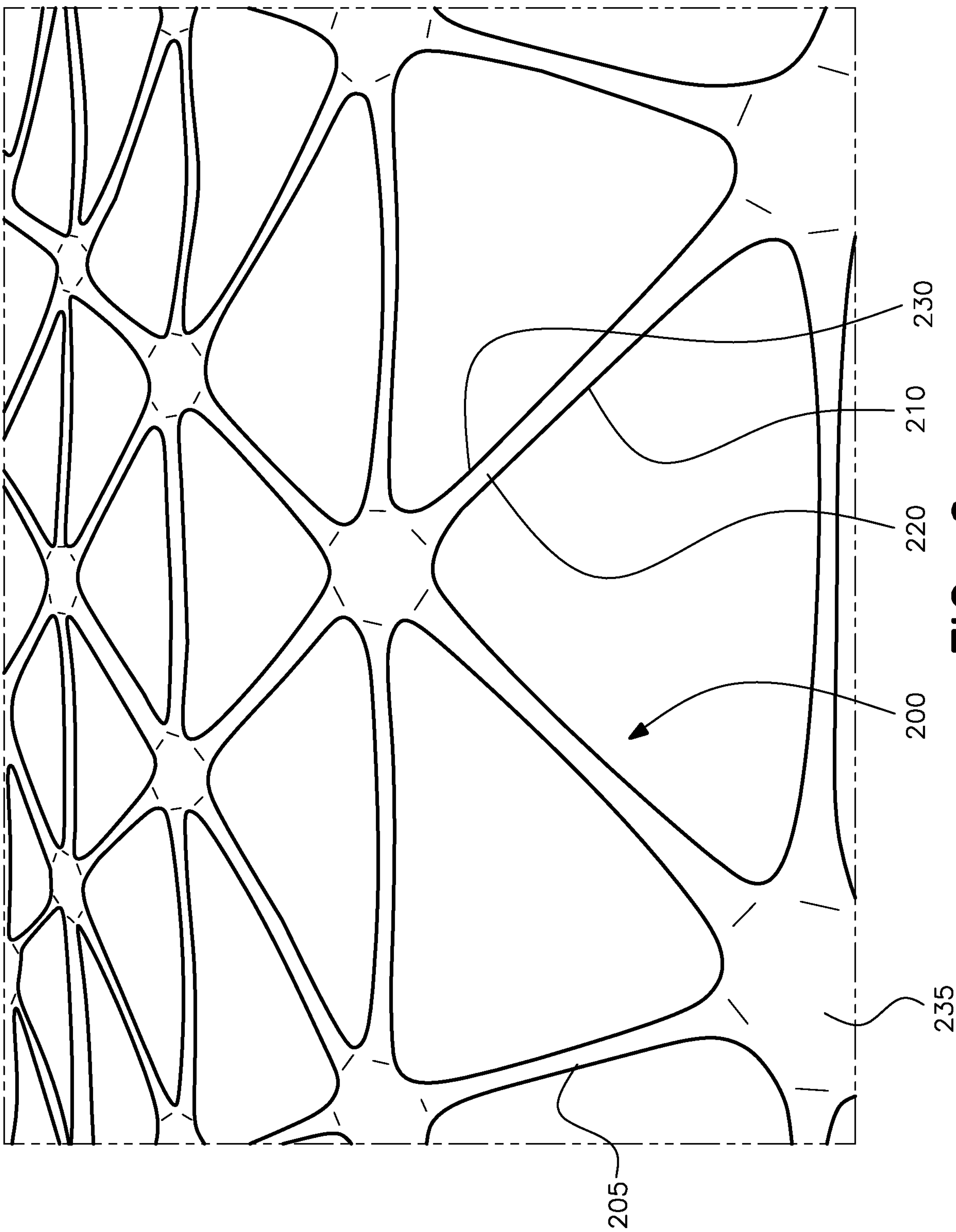

FIG. 6

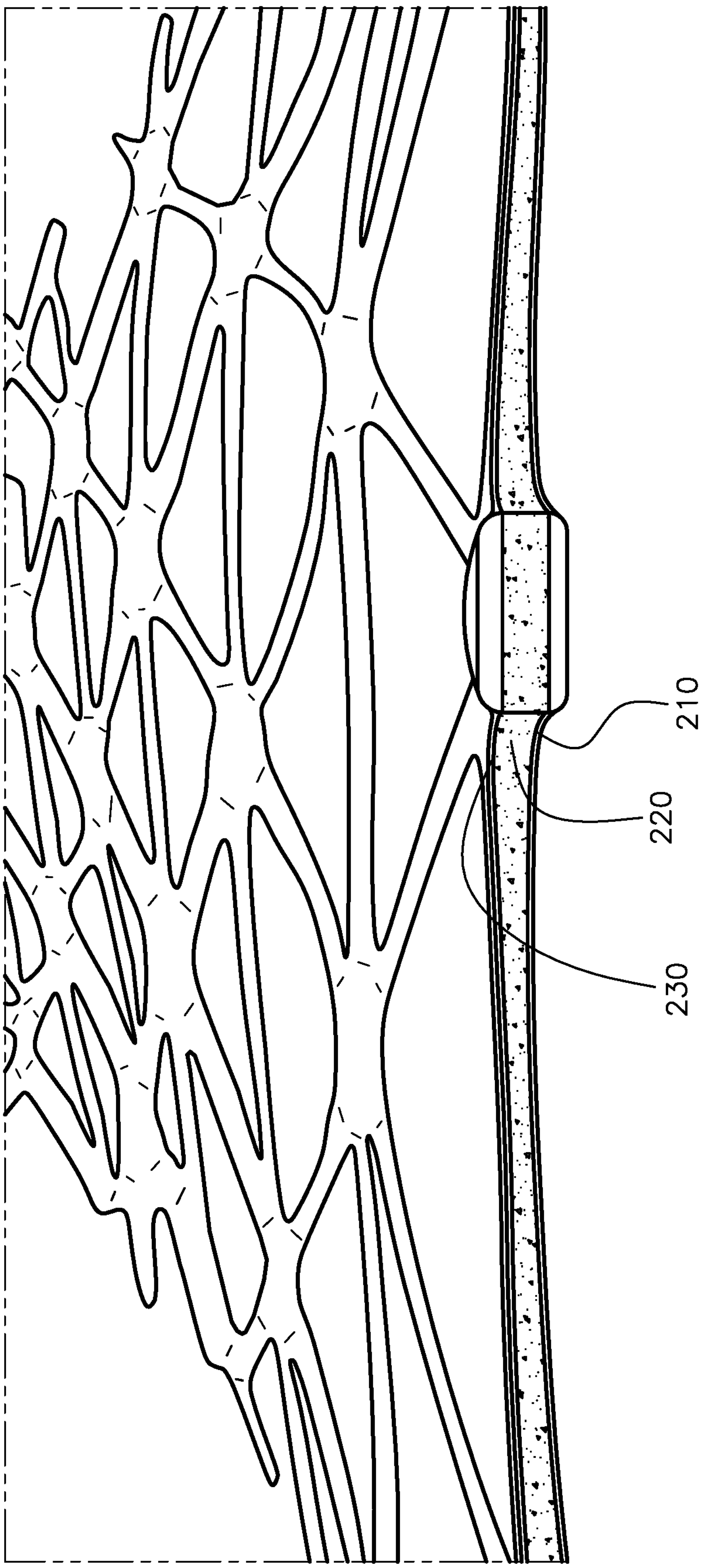

FIG. 7

Applied Moment (cm-kg)	Rotation (degrees)				Rotation	Aperture Stability Modulus (cm-kg/degree)		
Specimen 1	Load Cycle 1	Load Cycle 2	Load Cycle 3	Load Cycle 4	Average (degrees)	Average	Initial	Offset
5	2.10	1.30	1.50	1.50	1.60	3.10		
10	4.40	2.40	2.50	2.50	2.95	3.40		
15	6.40	3.50	3.60	3.50	4.25	3.50	3.70	3.50
20	8.10	4.50	4.60	4.50	5.43	3.70		
25	9.90	5.90	5.80	5.80	6.85	3.60		

Average Aperture Stability Modulus (cm-kg/degree)

FIG. 8

PRODUCT PROPERTIES	TEST METHOD	UNITS	TX160 (spec)		TX160 (AVG QC)		32% BSR 4.6mm sheet		50% BSR 4.6mm sheet		Virgin Lab	
Characteristics			MD	TD	MD	TD	MD	TD	MD	TD	MD	TD
Carbon Black	ASTM 4218	%	0.5		0.5		0.5		0.5		0.5	
Unit Weight	ASTM D3376	kg/m^2	0.223		0.220		0.210		0.214		0.203	
Load Capacity												
Tensile modulus at .5% Strain	ASTM D6637-01	lb/ft kN/m	750.0	750.0	900.0	950.0	1135.0	1050.0	1250.0	1200.0	1380.0	1300.0
Tensile modulus at 2% Strain	ASTM D6637-01	lb/ft kN/m	na	na	260.0	280.0	344.5	200.0	355.0	355.0	420.5	390.0
Tensile modulus at 5% Strain	ASTM D6637-01	lb/ft kN/m	na	na	196.0	210.0	254.0	136.0	256.0	254.0	311.8	284.0
Stuctural Integrity												
Junction Strength	GRI:GG2-87	lb/ft kN/m	21.4	18.6	12.6		15.9		17.6		17.0	
Junction Efficiency	GRI:GG2-87	%	93		92		103		119		104	
Junction Strength	GRI:GG2-01	lb N	862	750	563		651		677		707	
Flexural Stiffness (Overall)	ASTM D5732-95 [9]	mg-cm	575,000		860,000		1,150,939					
Aperture Stability (Torsional Rigidity)	Kinney-01	kg-cm/deg	3.2		3.8		na		6.2		na	

FIG. 9

PRODUCT PROPERTIES	TEST METHOD	UNITS	TX140 (spec)		TX140 (AVG QC)		SN20140407 3.0mm sheet		SN20140408 3.0mm sheet		SN20140409 3.0mm sheet	
Load Capacity			MD	TD	MD	TD	MD	TD	MD	TD	MD	TD
Tensile modulus at .5% Strain	ASTM D6637-01	lb/ft kN/m		220.0		300.0		280.0		320.0		300.0
Tensile modulus at 2% Strain	ASTM D6637-01	lb/ft kN/m		na		230.0		255.0		245.0		250.0
Tensile modulus at 5% Strain	ASTM D6637-01	lb/ft kN/m		na		176.0		190.0		182.0		180.0
Stuctural Integrity												
Flexural Stiffness (Overall)	ASTM D5732-95 [9]	mg-cm	250,000		389,981							
Aperture Stability (Torsional Rigidity)	Kinney-01	kg-cm/deg	3.0				4.5		na		na	

FIG. 10

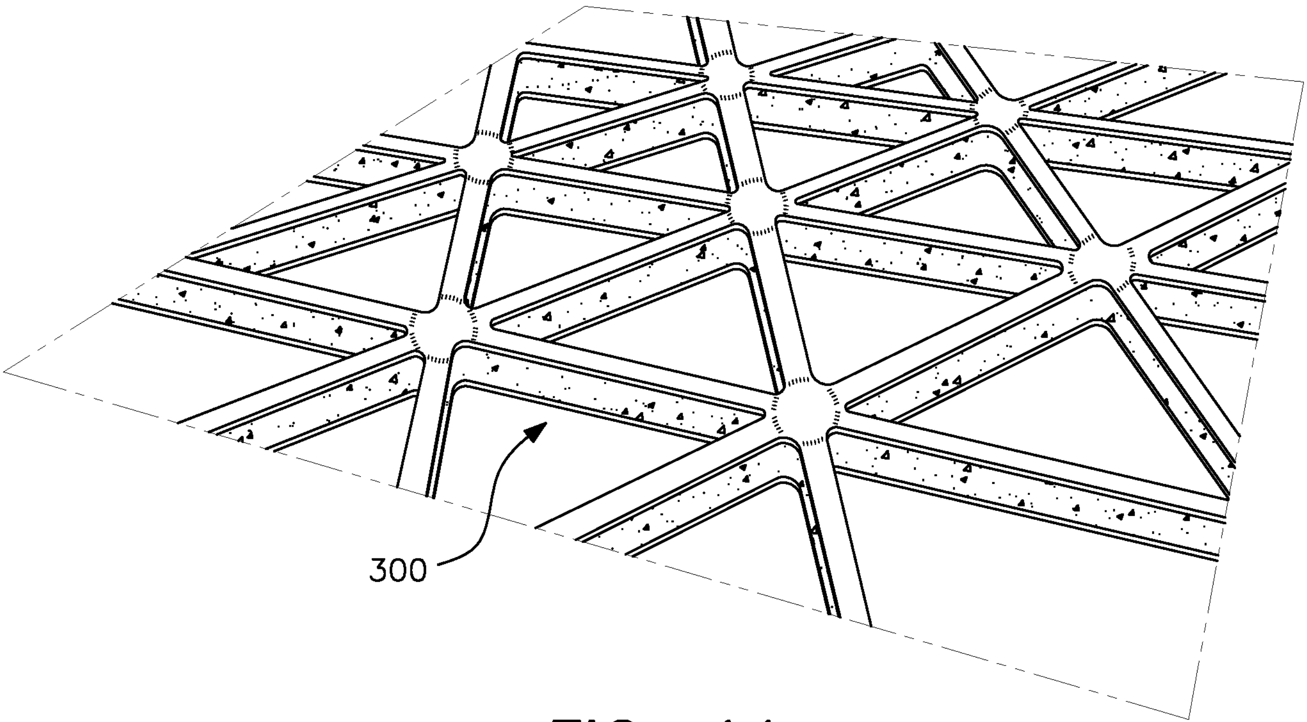

FIG. 11

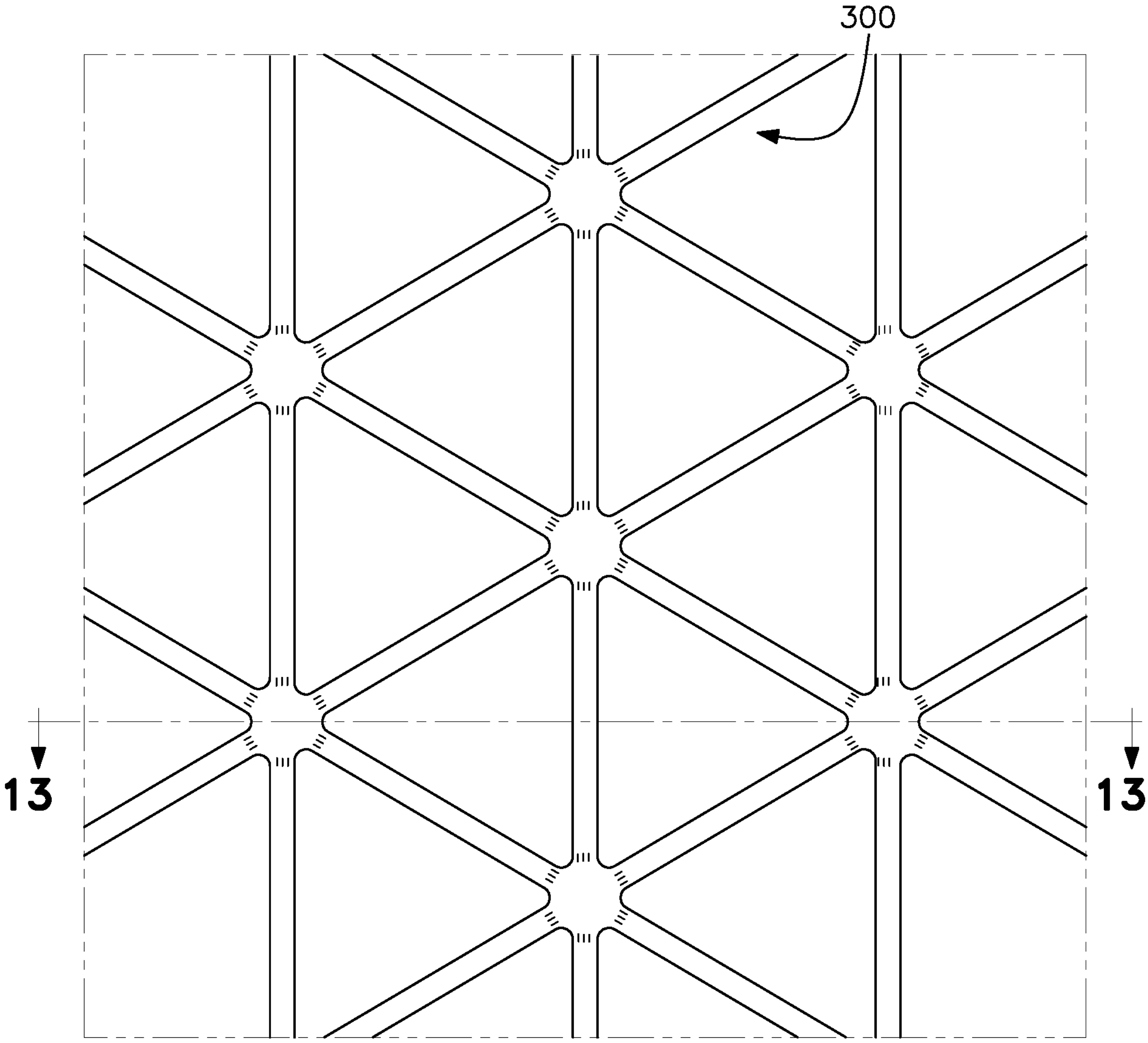

FIG. 12

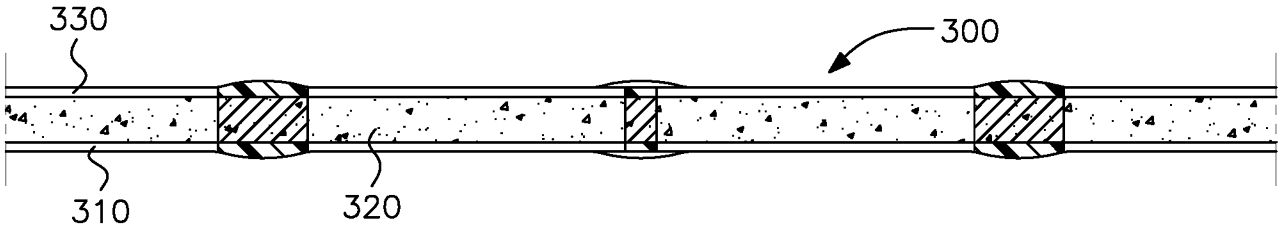

FIG. 13

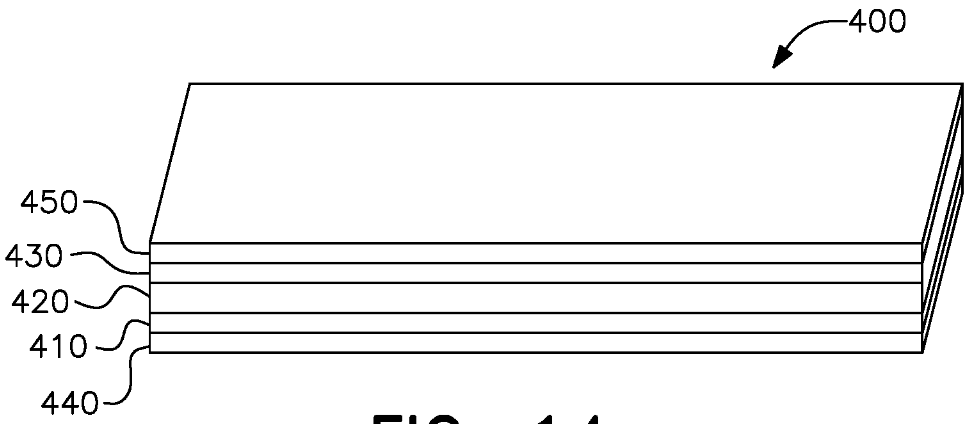

FIG. 14

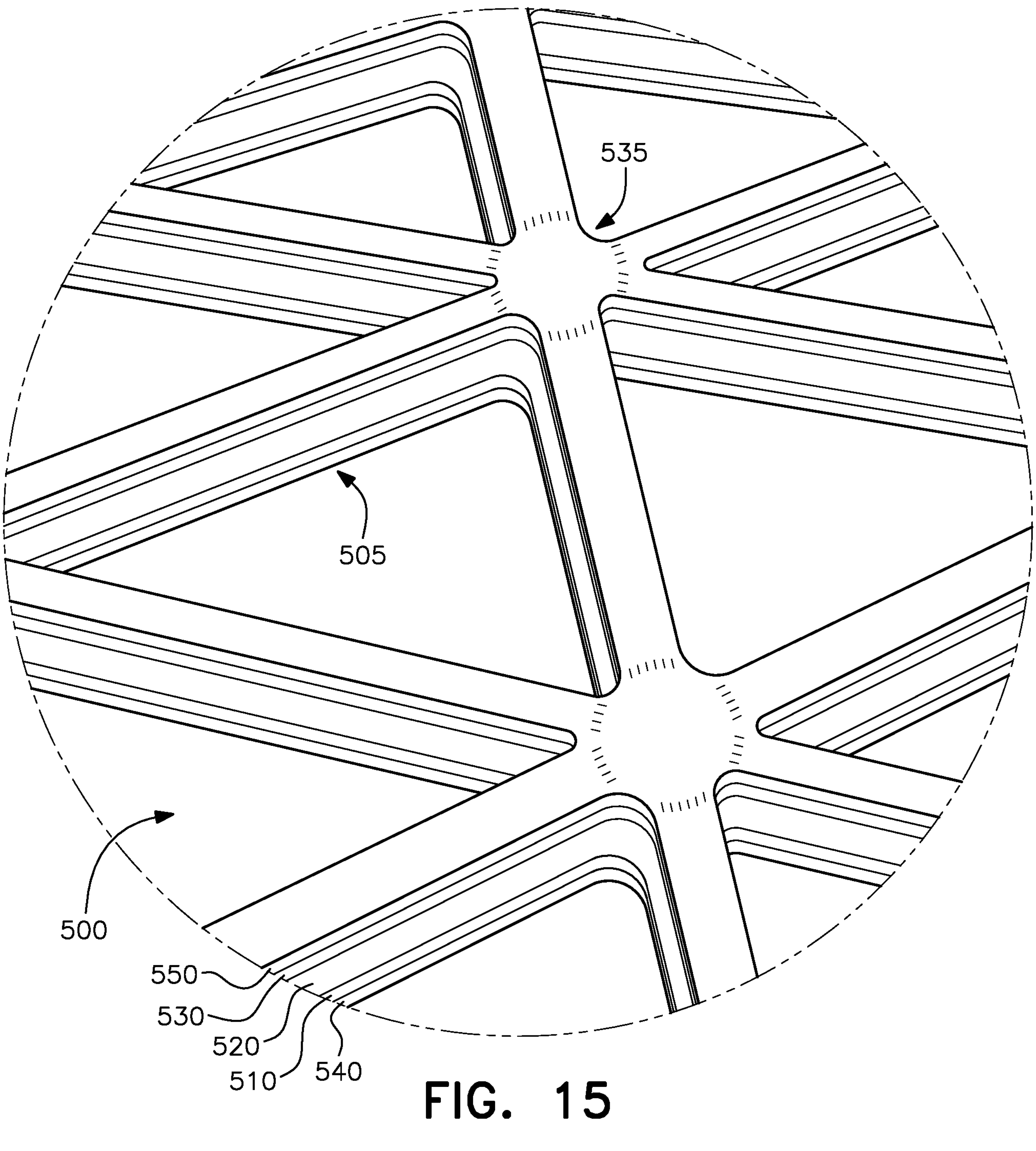

FIG. 15

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US16/55768

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - E02D 17/20, 29/02 (2016.01)
CPC - E02D 17/20, 17/202, 29/02, 29/0225, 29/0233, 29/0241, 29/025

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8) Classifications: E02D 3/00, 17/18 17/20, 29/02 (2016.01)
CPC Classifications: E02D 17/18, 17/20, 17/202, 29/02, 29/0225, 29/0233, 29/0241, 29/025 USPC Classifications: 405/262, 284

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PatSeer (US, EP, WO, JP, DE, GB, CN, FR, KR, ES, AU, IN, CA, INPADOC Data); geogrid, geoweb, geosynthetic, simultaneous, same time, together, co-extrude, extrude, multiple, plural, two, three four, layer, sheet, mesh, net, stretch, color, triangular, triaxial

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2009/0258212 A1 (JACOBY P.) October 15, 2009; abstract; figures 1-3; paragraphs [0071], [0078], [0088], [0104]	1-5, 8-14, 17-21, 26-28 --- 6, 7, 22-25
X --- Y	US 5,851,089 A (BERETTA M.) December 22, 1998; abstract; figures 1-3; column 1, lines 7-10; column 4, lines 17-27 and 45-47; claims 1, 5	1, 2, 4, 8-10, 12-18, 20, 23, 26, 27 --- 23-25, 28
Y	US 2004/0062615 A1 (WALSH A. T.) April 1, 2004; abstract; figure 4; paragraph [0012]	24, 25
Y	US 2008/0210359 A1 (HALAHMI I. et al.) September 4, 2008; paragraphs [0003], [0059], [0084]	28
Y	US 2005/0288404 A1 (SHELTON W. et al.) December 29, 2005; paragraph [0034]	6, 7, 22
Y	US 2010/0189509 A1 (FILSHILL A. et al.) July 29, 2010; paragraphs [0003], [0035]-[0037]	7

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
02 December 2016 (02.12.2016)	06 JAN 2017

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(71)申请人 坦萨有限责任公司

地址 美国佐治亚州

(72)发明人 威廉·斯坦利·谢尔顿

马诺伊·库马尔·亚吉

(74)专利代理机构 北京集佳知识产权代理有限公司 11227

代理人 蔡胜有 高世豪

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E02D 17/20(2006.01)

E02D 29/02(2006.01)

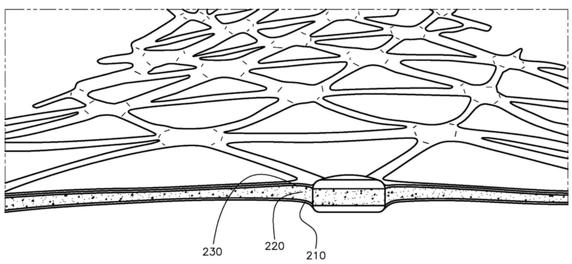
权利要求书2页 说明书9页 附图13页

(54)发明名称

由共挤出的多层聚合物制成的土工格栅

(57)摘要

整体式土工格栅包括其中具有开口阵列的多个相互连接的取向条，所述整体式土工格栅由共挤出的多层聚合物片起始材料制成。凭借该构造，共挤出的多层片组分在整体式土工格栅的挤出和取向期间提供结晶协同效应，导致提高的材料特性，这为整体式土工格栅在土壤土工合成材料增强方面的使用提供了性能益处。



CN 108350673 A

1.一种整体式土工格栅,包括其中具有开口阵列的多个相互连接的取向条,所述整体式土工格栅由共挤出的多层聚合物片生产。

2.根据权利要求1所述的整体式土工格栅,其中所述取向条已被单轴或双轴拉伸。

3.根据权利要求1所述的整体式土工格栅,其中所述共挤出的多层聚合物片包括第一层、第二层和第三层,其中所述第一层和所述第三层布置在所述第二层的相反平面表面上。

4.根据权利要求1所述的整体式土工格栅,其中所述共挤出的多层聚合物片的厚度为约2mm至约12mm。

5.根据权利要求3所述的整体式土工格栅,其中所述第一层的厚度为约0.5mm至约4.5mm,所述第二层的厚度为约1mm至约9mm,以及所述第三层的厚度为约0.5mm至约4.5mm。

6.根据权利要求3所述的整体式土工格栅,其中所述第一层具有高分子量聚烯烃的构造材料,所述第二层具有宽规格聚合物的构造材料,以及所述第三层具有高分子量聚烯烃的构造材料。

7.根据权利要求6所述的整体式土工格栅,其中所述第一层的所述高分子量聚烯烃为聚丙烯,所述第二层的所述宽规格聚合物为工业后的聚丙烯,以及所述第三层的所述高分子量聚烯烃为聚丙烯。

8.根据权利要求1所述的整体式土工格栅,其中所述多个相互连接的取向条包括通过基本上纵向取向的条相互连接的横向条。

9.根据权利要求1所述的整体式土工格栅,其中所述整体式土工格栅被配置用于结构或构造增强目的。

10.一种用于制造整体式土工格栅的起始材料,包括其中具有孔或凹陷的共挤出的多层聚合物片,所述孔或凹陷在所述片被单轴或双轴拉伸时提供开口。

11.根据权利要求10所述的起始材料,其中所述共挤出的多层聚合物片包括第一层、第二层和第三层,其中所述第一层和所述第三层布置在所述第二层的相反平面表面上。

12.根据权利要求10所述的起始材料,其中所述共挤出的多层聚合物片的初始厚度为至少2mm。

13.根据权利要求10所述的起始材料,其中所述共挤出的多层聚合物片的拉伸厚度为约0.2mm至约9mm。

14.根据权利要求10所述的起始材料,其中所述共挤出的多层聚合物片一旦被拉伸,就表现出相对于具有基本上相同的起始厚度的非共挤出片的抗弯刚度和抗扭刚度提高的抗弯刚度和抗扭刚度。

15.一种土壤构造,包括一定量的颗粒材料,所述一定量的颗粒材料通过在其中包埋根据权利要求1所述的整体式土工格栅而加固。

16.一种加固一定量的颗粒材料的方法,包括在所述一定量的颗粒材料中包埋根据权利要求1所述的整体式土工格栅。

17.一种制造整体式土工格栅的方法,包括:

提供共挤出的多层聚合物片;

在所述共挤出的多层聚合物片中提供图案化的多个孔或凹陷;以及

使其中具有所述图案化的多个孔或凹陷的所述共挤出的多层聚合物片取向以提供多个相互连接的取向条并将所述孔或凹陷配置为格栅开口。

18.根据权利要求17所述的方法,其中,其中具有所述图案化的多个孔或凹陷的所述共挤出的多层聚合物片通过单轴或双轴拉伸进行取向。

19.根据权利要求17所述的方法,其中所述共挤出的多层聚合物片包括第一层、第二层和第三层,其中所述第一层和所述第三层布置在所述第二层的相反平面表面上。

20.根据权利要求17所述的方法,其中所述共挤出的多层聚合物片的初始厚度为至少2mm。

21.根据权利要求17所述的方法,其中所述第一层的厚度为约0.5mm至约4.5mm,所述第二层的厚度为约1mm至约9mm,以及所述第三层的厚度为约0.5mm至约4.5mm。

22.根据权利要求17所述的方法,其中所述第一层具有高分子量聚烯烃的构造材料,所述第二层具有宽规格聚合物的构造材料,以及所述第三层具有高分子量聚烯烃的构造材料。

23.一种提供整体式土工格栅构造的方法,包括:

对作为其中具有图案化的多个孔或凹陷的共挤出的多层聚合物片的起始材料进行单轴或双轴拉伸,以提供具有多个取向条和多个格栅开口的整体式土工格栅;以及

将所述整体式土工格栅包埋在一定量的颗粒材料中。

24.根据权利要求1所述的整体式土工格栅,其中所述整体式土工格栅为三轴整体式土工格栅。

25.根据权利要求17所述的方法,其中所述整体式土工格栅为三轴整体式土工格栅。

26.根据权利要求17所述的方法,其中所述整体式土工格栅为单轴整体式土工格栅。

27.根据权利要求17所述的方法,其中所述整体式土工格栅为双轴整体式土工格栅。

28.根据权利要求17所述的方法,其中所述整体式土工格栅包括颜色标识层。

由共挤出的多层聚合物制成的土工格栅

[0001] 相关申请的交叉引用

[0002] 本申请要求于2015年10月9日提交的美国临时专利申请第62/239,416号的优先权的权益。

背景技术

1.技术领域

[0003] 本发明一般地涉及用于结构或构造增强及其他土工技术目的的整体式土工格栅和其他取向格栅。更具体地，本发明涉及这样的整体式土工格栅，其由共挤出的多层聚合物片制成以实现提高的刚度特性以及如本文所公开的其他期望特性。

[0004] 本发明还涉及生产这样的整体式土工格栅的方法。最后，本发明涉及这样的整体式土工格栅用于土壤和颗粒增强的用途以及这种增强的方法。

[0005] 出于本发明的目的，术语“整体式土工格栅”旨在包括整体式土工格栅和其他整体式格栅结构，其通过使必要厚度的片或片状形状形式的聚合物起始材料取向(拉伸)并在其中制成或形成有孔或凹陷来制成。

[0006] 2.现有技术描述

[0007] 具有由基本上平行的取向条(strand)及其间的接合点的各种几何图案限定的网开口的聚合物整体式格栅结构(例如整体式土工格栅)已经制造了超过25年。这样的格栅通过将一体浇注的片挤出来制造，所述片经受限定图案的孔或凹陷，随后使片经受受控的单轴或双轴拉伸和取向成由孔或凹陷形成的网开口限定的高度取向的条和部分取向的接合点。片在单轴或双轴方向上的这种拉伸和取向在相应的拉伸方向上产生条抗拉强度和模量。这些整体取向的聚合物格栅结构可以用于保持或稳定任何合适形式的颗粒材料(例如土壤、土、沙、粘土、砾石等)，并且可以用在任何合适的位置，例如在道路或其他通道或路堤的侧面，在道路表面下方、跑道表面等。

[0008] 已对多种形状和图案的孔进行了实验以实现更高水平的强度重量比，或者在制造过程期间实现更快的加工速度。取向在受控的温度和应变速率下完成。该过程中的一些变量包括拉伸比、分子量、分子量分布以及聚合物的支化程度或交联程度。

[0009] 这样的整体式土工格栅和其他整体式格栅结构的制造和使用可以通过公知技术来完成。如Mercer的美国专利第4,374,798号、Mercer的美国专利第4,590,029号、Mercer和Martin的美国专利第4,743,486号、Mercer的美国专利第4,756,946号以及Mercer的美国专利第5,419,659号中详细描述的，首先将起始聚合物片材挤出，然后冲孔以形成必要限定图案的孔或凹陷。然后通过对经冲孔的片材进行必要的拉伸和取向来形成整体式土工格栅。

[0010] 这样的整体式土工格栅，单轴整体式土工格栅和双轴整体式土工格栅二者(统称为“整体式土工格栅”，或者单独称为“单轴整体式土工格栅”或“双轴整体式土工格栅”)由上面提到的Mercer在20世纪70年代末发明，在过去的30年里取得了巨大的商业成功，彻底革新了增强由颗粒状或颗粒材料制成的土壤、道路下层铺面和其他土木工程结构的技术。

[0011] Mercer发现，通过从相对厚的基本为单平面的聚合物起始片(优选大约1.5mm(0.059055英寸)至4.0mm(0.15748英寸)厚，具有其中心位于假想的大致方形或矩形格栅的行和列上的孔或凹陷图案)开始，并对起始片进行单向或双向拉伸使得条的取向延伸至接合点，可以形成全新的基本为单平面的整体式土工格栅。如Mercer所描述的，“单平面的”意指片状材料的所有区域关于该片状材料的中间平面对称。

[0012] 在美国专利第3,252,181号、第3,317,951号、第3,496,965号、第4,470,942号、第4,808,358号和第5,053,264号中，具有必要图案的孔或凹陷的起始材料连同圆柱形聚合物挤出物一起形成，并且通过使挤出物经过胀开式心轴(expanding mandrel)来实现基本上单平面的。然后将经扩张的圆柱体纵向切割以产生平坦的基本为单平面的起始片。

[0013] 在转让给Tensar国际有限公司(佐治亚州亚特兰大市的Tensar International Corporation,Inc.(下文中为“Tensar”)的本专利申请的受让人的联营公司)的Walsh的美国专利第7,001,112号(下文中为“Walsh'112专利”)中描述了另一种整体式土工格栅。Walsh'112专利公开了取向聚合物整体式土工格栅，其包括双轴拉伸的整体式土工格栅，其中取向条形成三角形网开口，每个角处具有部分取向的接合点，并且六个高度取向的条在每个接合点处相遇(下文中，有时将此处称为“三轴整体式土工格栅”)。

[0014] 旨在无论起始片形成的方法或使起始材料取向成整体式土工格栅或格栅结构的方法如何，本发明都适用于所有整体式格栅。上述专利第3,252,181号、第3,317,951号、第3,496,965号、第4,470,942号、第4,808,358号、第5,053,264号和第7,001,112号的主题通过引用明确地并入本说明书中，如同这些公开内容在本文中完整阐述一样。这些专利被引用为说明性的，并且不被认为是包含性的，或者排除本领域已知的用于生产整体式聚合物格栅材料的其他技术。

[0015] 传统上，用于生产整体式土工格栅的聚合物材料为高分子量均聚物或共聚物聚丙烯和高密度高分子量聚乙烯。将各种添加剂如紫外光抑制剂、炭黑、加工助剂等添加到这些聚合物中以实现成品和/或制造效率的期望效果。

[0016] 并且，传统上，用于生产这样的整体式土工格栅的起始材料通常是具有单层构造的单平面片，即均匀的单层聚合物材料。

[0017] 虽然由上述常规起始材料生产的整体式土工格栅表现出一般地令人满意的特性，但是在结构上和经济上有利的是生产这样的整体式土工格栅，其具有适于诸如土工合成增强的使用需求的相对较高程度的刚度或具有特定的土工合成应用所期望的其他特性。

[0018] 因此，需要一种起始材料，其不仅适于与生产整体式土工格栅相关的工艺限制，而且一旦整体式土工格栅被生产并进行使用，就提供与常规土工格栅起始材料相关的刚度相比较高程度的刚度或提供通过目前的单层整体式土工格栅无法获得的其他期望特性。

发明内容

[0019] 为了获得上述较高程度的刚度和其他期望特性，本发明采用共挤出的多层聚合物片作为起始材料用于制造整体式土工格栅。

[0020] 本文中描述的实验支持本发明人的理论，即凭借本发明的构造，共挤出的多层片组分在挤出和取向期间提供结结晶协同效应，导致提高的材料特性，这为整体式土工格栅在土壤土工合成材料增强方面的使用提供了性能益处。

[0021] 根据本发明的一个实施方案，用于制成整体式土工格栅的起始材料包括其中具有孔或凹陷的共挤出的多层聚合物片，所述孔或凹陷在起始材料被单轴或双轴拉伸时提供开口。

[0022] 根据本发明的另一个实施方案，整体式土工格栅包括多个高度取向的条，其通过部分取向的接合点相互连接并且其中具有由共挤出的多层聚合物片产生的开口阵列。根据本发明的一个实施方案，整体式土工格栅为三轴整体式土工格栅。

[0023] 根据本发明的又一个实施方案，土壤构造包括一定量的颗粒材料，该一定量的颗粒材料通过在其中包埋由共挤出的多层聚合物片生产的整体式土工格栅而加固。

[0024] 根据本发明的再一个实施方案，制造用于整体式土工格栅的起始材料的方法包括提供共挤出的多层聚合物片，以及在其中提供孔或凹陷。

[0025] 根据本发明的另一个实施方案，制造整体式土工格栅的方法包括提供共挤出的多层聚合物片，在其中提供孔或凹陷，以及对其中具有孔或凹陷的共挤出的多层聚合物片进行单轴或双轴拉伸以提供多个高度取向的条，其通过部分取向的接合点相互连接并且其中具有开口阵列。根据本发明的一个实施方案，该方法由共挤出的多层聚合物片来生产三轴整体式土工格栅。

[0026] 并且，根据本发明的又一个实施方案，加固一定量的颗粒材料的方法包括在一定量的颗粒材料中包埋由共挤出的多层聚合物片生产的整体式土工格栅。

[0027] 因此，本发明的一个目的是提供用于制造整体式土工格栅的起始材料。起始材料包括其中具有孔或凹陷的共挤出的多层聚合物片，所述孔或凹陷在起始材料被单轴或双轴拉伸时提供开口。

[0028] 本发明的另一个目的是提供具有多个高度取向的条的整体式土工格栅，其通过部分取向的接合点相互连接并且其中具有由共挤出的多层聚合物片产生的开口阵列。本发明的一个相关目的是提供一种整体式土工格栅，其特征在于较高程度的刚度、较大的强度和其他期望特性。具体地，本发明的一个目的是由共挤出的多层聚合物片提供三轴整体式土工格栅。

[0029] 本发明的又一个目的是提供一种土壤构造，其包括通过在其中包埋由共挤出的多层聚合物片生产的整体式土工格栅而加固的一定量的颗粒材料。

[0030] 本发明的再一个目的是提供制成用于整体式土工格栅的起始材料的方法，该方法包括提供共挤出的多层聚合物片，以及在其中提供孔或凹陷。

[0031] 本发明的另一个目的是提供制造整体式土工格栅的方法。该方法包括提供共挤出的多层聚合物片，在其中提供孔或凹陷，以及对其中具有孔或凹陷的共挤出的多层聚合物片进行单轴或双轴拉伸以提供多个高度取向的条，其通过部分取向的接合点相互连接并且其中具有开口阵列。该方法可以采用已知的土工格栅制造方法，例如在上述美国专利第4,374,798号、第4,590,029号、第4,743,486号、第5,419,659号和第7,001,112号以及其他专利中描述的方法。具体地，本发明的目的是提供由共挤出的多层聚合物片制成三轴整体式土工格栅的方法。

[0032] 并且，本发明的又一个目的是提供通过在一定量的颗粒材料中包埋由共挤出的多层聚合物片生产的整体式土工格栅来加固一定量的颗粒材料的方法。

[0033] 这些以及随后将变得明显的其他目的和优点存在于下文中更充分描述的构造和

操作的细节中，并且参照形成其一部分的附图，其中同样的附图标记始终表示同样的部分。附图旨在说明本发明，但不一定按比例。

附图说明

[0034] 图1示出了根据本发明的一个实施方案的在其中形成孔或凹陷之前的用于整体式土工格栅的共挤出的单平面多层片起始材料。

[0035] 图2是图1中示出的起始材料片的透视平面图，所述起始材料片具有经冲压的孔以形成Walsh'112专利中所示类型的三轴整体式土工格栅。

[0036] 图3是图2中所示的起始材料片的一部分的侧视图。

[0037] 图4是通过使图2中所示的起始材料片双轴取向而生产的三轴整体式土工格栅的一部分的平面图。

[0038] 图5是图4中所示的三轴整体式土工格栅的一部分的透视图。

[0039] 图6是图4中所示的三轴整体式土工格栅的一部分的放大透视图。

[0040] 图7是图4中所示的三轴整体式土工格栅的一部分的侧视截面图。

[0041] 图8是汇总由3mm共挤出的单平面多层片起始材料(例如图1至7中所示)生产的实验三轴整体式土工格栅的孔稳定性模量特性与商购自Tensar的作为TriAx® TX140™土工格栅的三轴整体式土工格栅的相似特性进行比较的表格。

[0042] 图9是将商购自Tensar的三轴整体式土工格栅(由挤出的单层片生产)的多个产品特性与根据本发明的如图4至7所示的由共挤出的单平面多层片生产的实验三轴整体式土工格栅的相应多个产品特性进行比较的表格。

[0043] 图10是将商购自Tensar的三轴整体式土工格栅(由挤出的单层片生产)的多个产品特性与根据本发明的由共挤出的单平面多层片生产的实验三轴整体式土工格栅的相应产品特性进行比较的另一个表格。

[0044] 图11是根据本发明的另一个实施方案的三轴整体式土工格栅的一部分的透视图。

[0045] 图12是图11中所示的三轴整体式土工格栅的一部分的平面图。

[0046] 图13是图11中所示的三轴整体式土工格栅的一部分的侧视截面图。

[0047] 图14示出了根据本发明的另一个实施方案的在其中形成孔或凹陷之前的用于整体式土工格栅的共挤出的单平面多层片起始材料。

[0048] 图15是与图14中所示的起始材料片相关联的三轴整体式土工格栅的一部分的透视图。

具体实施方式

[0049] 虽然仅详细说明了本发明的优选实施方案，但是应理解，本发明的范围不限于以下描述中阐述的或附图中示出的组件的构造和布置的细节。本发明能够具有其他实施方案以及能够以多种方式实践或进行。

[0050] 此外，在描述优选实施方案时，为了清楚起见将采用术语。旨在使每个术语考虑了本领域技术人员所理解的其最广泛的含义，并且包括以相似方式操作以实现相似目的的所有技术等同物。

[0051] 并且，如本文所使用的术语“共挤出(coextruded)”、“共挤出(coextruding)”和

“共挤出(coextrusion)”根据它们通常接受的定义来使用，即涉及这样的单步过程：起始于两种或更多种聚合物材料，将其在单个模具中同时挤出并成型以形成多层片。

[0052] 本发明涉及由共挤出的多层聚合物片作为起始材料生产的单轴、双轴和三轴整体式土工格栅结构。根据待由其制造的多层土工格栅结构所期望的特定特性，共挤出的多层聚合物片起始材料可以是例如单平面的或者可以是非单平面的。根据本发明的优选实施方案，共挤出的多层聚合物片起始材料为单平面或基本为单平面的。

[0053] 本发明基于以下事实：当通过片冲孔和炉拉伸过程被转化成单轴、双轴和/或三轴整体式土工格栅时，由不同百分比含量的不同聚合物材料或其他可挤出材料组成的共挤出的多层片的挤出产生了相对于用于土壤增强和其他土工技术应用的目的的传统的单轴、双轴和三轴土工格栅具有独特特性的成品。

[0054] 图1示出了在对片进行穿通(through-punch)或在其中形成凹陷之前的根据本发明的一个实施方案的用作用于整体式土工格栅的起始材料的共挤出的多层片100。

[0055] 如图1所示，共挤出的多层片100为本发明的三层片实施方案。即，优选地，片100包括第一层110、第二层120和第三层130。第一层110和第三层130布置在第二层120的相反平面表面上，优选布置成单平面或基本为单平面的配置。此外，虽然为了说明的目的示出了三层构造的片100，但是本发明考虑了使用具有以多种配置布置的多个层、具有多种厚度的组合的多个层、以及具有多种构造材料的多个层的片，全部都取决于其中待采用整体式土工格栅的特定应用。例如，虽然为了说明的目的示出了三层构造的片100，但是本发明也考虑了使用具有多于三层的共挤出片。通常，层配置、层厚度和层的构造材料被选择为不仅提供整体式土工格栅的制造的容易性，而且提供具有期望程度的刚度和其他性能特性的整体式土工格栅。

[0056] 如上所述，根据本发明的用作用于整体式土工格栅的起始材料的共挤出的多层片100优选为穿通的，但可以使用形成在其中的凹陷来代替。根据其中片中形成有凹陷的起始材料的实施方案，凹陷设置在片的每一侧上，即在片的顶部和底部二者上。此外，凹陷延伸至共挤出的多层片的每个层中。

[0057] 在图1所示的本发明的特定实施方案中，片100通过将形成第一层110的第一材料、形成第二层120的第二材料和形成第三层的第三材料层130以本领域技术人员已知的挤出多层片的方式共挤出来制造。

[0058] 根据本发明的一个优选实施方案，片100的总厚度为约2mm至约12mm，并且根据本发明的一个更优选实施方案，片100的总厚度为约2mm至约6mm。

[0059] 关于片层的各个厚度，根据本发明的一个优选实施方案，第一层110的厚度为约0.5mm至约4.5mm，第二层120的厚度为约1mm至约9mm，并且第三层130的厚度为约0.5mm至约4.5mm，应记住片100的总厚度为约2mm至约12mm。并且，根据本发明的一个更优选实施方案，第一层110的厚度为约0.5mm至约2mm，第二层120的厚度为约2mm至约5mm，并且第三层130的厚度为约0.5mm至约2mm。

[0060] 通常，第一层110、第二层120和第三层130的构造材料可以彼此相同，或者可以彼此不同。优选地，第一层110的构造材料和第三层130的构造材料可以彼此相同，或者可以彼此不同。更优选地，第二层120的构造材料不同于第一层110的构造材料和第三层130的构造材料二者。

[0061] 并且，通常，片的层本质上是聚合物。例如，构造材料可包括高分子量聚烯烃和宽规格聚合物(broad specification polymer)。此外，聚合物材料可为原生材料，或者可为回收再利用材料，例如工业后(post-industrial)或消费后回收再利用的聚合物材料。并且，还考虑使用比上述高分子量聚烯烃和宽规格聚合物成本更低的一个或更多个聚合物层。相对于使用例如聚丙烯层，使用这种较低成本的聚合物层可导致成本节约大约20％至大约30％。

[0062] 根据本发明的一个优选实施方案，第一层110和第三层130的构造材料为高分子量聚烯烃，例如聚丙烯(“PP”)。并且，根据同一优选实施方案，第二层120的构造材料为宽规格聚合物，例如原生PP或回收再利用PP，例如工业后的PP或其他回收再利用PP。然而，根据整体式土工格栅的特定应用，具有除聚丙烯之外的构造材料的聚合物组分可被包含在共挤出的多层片中。

[0063] 图2和3示出了图1的其中冲压有孔140的共挤出的多层片起始材料100，用于形成图4、5和6所示的三轴整体式土工格栅200。孔140的尺寸和间距如Walsh'112专利中所公开的。同样如Walsh'112专利中所公开的，三轴整体式土工格栅200包括高度取向的条205和部分取向的接合点235。起始材料100的上层130已被拉伸并取向成条205和接合点235的上层230。类似地，起始材料100的第三层或下层110已被拉伸并取向成条205和接合点235的下层或下面层210。当第一层130和第三层110被拉伸并取向时，第二层或中间层120也被拉伸并取向成条205和接合点235二者的中间层220。

[0064] 本发明还涉及制造上述三轴整体式土工格栅200的方法。该方法包括：提供共挤出的多层聚合物片100；例如根据Walsh'112专利的公开内容，以选定的图案在共挤出的多层聚合物片100中形成多个孔或凹陷；以及对其中具有图案化的多个孔或凹陷的共挤出的多层聚合物片进行双轴拉伸并取向，以形成在部分取向的接合点之间具有多个相互连接的取向条并将孔或凹陷配置为格栅开口的整体式土工格栅。

[0065] 通常，一旦共挤出的多层聚合物片100制备有孔或凹陷，就可以根据上述专利中描述的并且本领域技术人员已知的方法由片100生产三轴整体式土工格栅200。

[0066] 为了证明由共挤出的多层片生产的本发明整体式土工格栅的提高的特性和性质，进行了比较试验。

[0067] 图8为汇总由3mm共挤出片起始材料生产的实验三轴整体式土工格栅的与商购自Tensar的作为TriAx® TX140™土工格栅的三轴整体式土工格栅的相似特性进行比较的孔稳定性模量特性的表格。根据ASTM D7864的测试方案(即，“Standard Test Method for Determining the Aperture Stability Modulus of Geogrids”)进行实验。对由包含50％BSR(“宽规格树脂”)已冲孔和拉伸的3mm厚的共挤出的多层片制成的三轴整体式土工格栅样品进行孔稳定性测试。共挤出的多层片的第一层(即下层)110具有高分子量聚丙烯(PP)的构造材料和0.75mm的厚度；第二层(即中间层)120具有宽规格PP的构造材料和1.50mm的厚度；并且第三层(即上层)130具有高分子量PP的构造材料和0.75mm的厚度。

[0068] 对于由共挤出的多层片制成的实验性实验室制备的三轴整体式土工格栅，对20cm-kg力矩的平均值为3.70cm-kg/度。相反，对于非共挤出片(即单层片)，特别是标准Triax® TX140™土工格栅的六次测试，测试的平均值为2.86cm-kg/度，范围为2.52cm-kg/度至3.14cm-kg/度，显著低于所记录的实验多层样品的平均值。

[0069] 图9还示出了由单层挤出片生产的三轴整体式土工格栅的多个产品特性与由根据本发明的共挤出的多层片生产的三轴整体式土工格栅的相应产品特性。在图9中汇总的测试中，单层片被加工成具有Walsh'112专利中描述的三轴整体式土工格栅的配置。这样的三轴整体式土工格栅可商购自Tensar，并且被称为TriAx®TX160™土工格栅。

[0070] 为了图9中所示的比较实验，制备4.6mm成品片厚度的共挤出的3层片。不同片包含不同载量的工业后的聚丙烯(PP)含量，然后将每个共挤出的3层片加工成与Tensar的TriAx®TX160™土工格栅相当的三轴整体式土工格栅。

[0071] 关于图9，每个4.6mm共挤出的多层片包含以下层组成：样品(1)：如上所述的第一层或上层130，34％原生聚丙烯(PP)和黑色母料(“MB”，即炭黑，为产品提供黑色用于UV保护)/如上所述的第二层或中间层120，32％工业后的PP/以及如上所述的第三层或下层110，34％原生PP和MB；以及样品(2)：25％原生PP和MB/50％工业后的PP/25％原生PP和MB。

[0072] 上述多个片样品(1)和(2)的层各自的厚度如下。对于4.6mm多层片样品(1)，层的厚度分别为：1.56mm/1.47mm/1.56mm。对于4.6mm多层片样品(2)，层的厚度分别为：1.15mm/2.30mm/1.15mm。

[0073] 如从图9中呈现的结果明显的，与具有近似相等的起始片厚度(4.7mm)的标准单层Triax® TX160™土工格栅相比，由上述经冲孔和取向的4.6mm共挤出的3层片样品生产的所得实验三轴整体式土工格栅产生了这样的产品：如根据标准Tensar低应变拉伸模量测试、抗弯刚度测试和孔稳定性测试所测量的，其表现出显著较高的产品刚度。由4.6mm共挤出的3层起始片生产的实验三轴土工格栅比由4.7mm单层片生产的常规Triax® TX160™土工格栅的0.5％和2.0％应变拉伸模量测试值高超过30％。类似地，由4.6mm共挤出片生产的实验三轴土工格栅比由4.7mm单层起始片制成的标准Triax® TX160™土工格栅的抗弯刚度高超过33％。

[0074] 图10是将商购自Tensar的单层片生产的三轴整体式土工格栅的多个产品特性与根据本发明的由共挤出的多层片生产的实验三轴整体式土工格栅的相应产品特性进行比较的另一个表格。在图10中汇总的测试中，单层片也被处理成具有Walsh'112专利中描述的三轴整体式土工格栅的配置。这样的三轴整体式土工格栅可商购自Tensar，并且被称为TriAx®TX140™土工格栅。

[0075] 为了图10中所示的比较实验，制备3.0mm成品片厚度的共挤出的3层片。多个片包含不同载量的工业后的聚丙烯(PP)含量，然后将每个共挤出的3层片加工成与Tensar的TriAx®TX160™土工格栅相当的三轴整体式土工格栅。

[0076] 关于图10，片“SN20140407”具有以下组成：在第二(即中间)层120中，32％宽规格树脂；以及在第一(即顶)层130和第三(即下部)层110中，34％高分子量PP。片“SN20140408”具有以下组成：在第二(即中间)层中，50％宽规格树脂；以及在第一层和第三层中，25％高分子量PP。片“SN20140409”具有以下组成：在第二(即中间)层中，60％宽规格树脂；以及在第一层和第三层中，20％高分子量PP。

[0077] 上述片SN20140407、片SN20140408和片SN20140409的层各自的厚度如下。对于3mm多层片SN20140407，第一层、第二层和第三层的厚度分别为：1.02mm/0.96mm/1.02mm。对于3mm多层片SN20140408，层的厚度分别为：0.75mm/1.5mm/0.75mm。对于3mm多层片

SN20140409，层的厚度分别为：0.6mm/1.8mm/0.6mm。

[0078] 如从图10中报道的结果明显的，当被转化为成品三轴整体式土工格栅时，工业后的PP含量为32％(SN20140407)、50％(SN20140408)和60％(SN20140409)的3.0mm起始片厚度超过了唯一指明的由3.7mm厚度片生产的Triax®TX140™土工格栅的拉伸模量测试值(在横向方向(“TD”)上为220kN/m)。图10还显示，每个起始于较薄的3.0mm片的共挤出样品达到或超过由3.7mm片生产的标准Triax®TX140™土工格栅的平均拉伸模量值。

[0079] 此外，本文中描述的实验支持本发明人的构思，即凭借利用起始材料片的多层结构，共挤出的多层片组分可在挤出和取向期间提供结晶协同效应，从而在所得整体式土工格栅中提供增强的材料特性并且当在土壤和其他土工技术应用中使用所得土工格栅时提供性能益处。

[0080] 本发明的其他可能的实施方案可以包括例如：(1)具有显著较高水平的工业后和消费后的PP树脂(即相对低成本的PP树脂)的多层共挤出的聚合物片起始材料，(2)发泡剂以提供发泡或膨胀的第二(即中间)层，(3)包含填充剂(bulking agent)或填料的一个或更多个相对低成本的层，(4)整体式土工格栅内的颜色标识层，以及(5)具有HDPE外层和夹在其间的无定形和结晶聚酯内层的3层共挤出的聚合物片。每个上述实例将提供增强或满足对具有增强的土工合成骨料增强、成本降低和/或标识特性的整体式土工格栅的需求。

[0081] 更具体地，如上所述，本发明的一个可能的实施方案可以包括使用发泡剂以提供发泡或膨胀的第二层或中间层。图11、12和13涉及这样的实施方案300，其中共挤出的多层片的第二层或中间层(在此指定为320)形成膨胀或“发泡”结构。即，根据本发明的这个实施方案，化学发泡剂与被挤出的聚合物混合以形成第二层。产生以使聚合物熔融的热使化学发泡剂分解，这导致气体的释放。然后气体分散在聚合物熔体中，并在离开模具时膨胀。作为结果，第二层膨胀或发泡(见图13，其为图11中所示的整体式三轴土工格栅的一部分面的侧视截面图)。

[0082] 根据本发明的这个实施方案，与上述第一实施方案一样，第一层(在此为310)的构造材料与第三层(在此为330)的构造材料可以彼此相同，或者可以彼此不同，但是相同的材料是优选的。通常，第二层320的构造材料不同于第一层310的构造材料和第三层330的构造材料二者。

[0083] 根据本发明的成品整体式土工格栅的发泡实施方案的优点不仅包括降低的原材料成本和降低的土工格栅重量，而且还可包括发泡层本身的期望的物理和化学特性。

[0084] 如上所述，本发明的一个可能的实施方案可以包括在整体式土工格栅中使用颜色标识层。例如，美国国家公路与运输协会(“AASHTO”)连同国家运输产品评估计划(“NTPEP”)要求与墙壁、斜坡和软土地上的填料相关的土工合成材料增强的产品标记。

[0085] 上述颜色标识层可以是例如颜色与相邻或相关共挤出层的颜色不同的聚合物层。颜色标识层可以是整体式土工格栅的内层或外层，或者整体式土工格栅可以包括具有相同颜色或多种颜色的多个颜色标识层。颜色标识层可以是纯色，或者可以具有图案(例如，包含条纹)。当然，基于整体式土工格栅的特定应用的要求来选择颜色标识层的颜色和/或化学特性。

[0086] 除了上述符合AASHTO和NTPEP标准的整体式土工格栅的颜色标识层的使用之外，颜色标识层还可用于提供整体式土工格栅的来源标识。

[0087] 如上所述，虽然为了说明的目的已示出了三层构造的片100，但是本发明也考虑使用具有多于三层的共挤出片。

[0088] 例如，共挤出片可以是五层构造，例如图14中所示的片400。片400包括中间层420、第一内层410、第二内层430、第一外层440和第二外层450。第一内层410和第二内层430布置在中间层420的相反平面表面上，优选布置成单平面或基本为单平面的配置。第一外层440和第二外层450分别布置在第一内层410和第二内层430的相反平面表面上，优选布置成单平面或基本为单平面的配置。

[0089] 在图14中所示的本发明的特定实施方案中，片400通过将形成中间层420的第一材料、形成第一内层410的第二材料、形成第二内层430的第三材料、形成第一外层440的第四材料以及形成第二外层450的第五材料以本领域技术人员已知的挤出多层片的方式共挤出来制造。

[0090] 通常，中间层420、第一内层410、第二内层430、第一外层440和第二外层450的构造材料可以彼此相同，或者可以彼此不同。例如，中间层420可具有第一构造材料，第一内层410和第二内层430可具有第二构造材料，并且第一外层440和第二外层450可具有第三构造材料。总之，根据其中待采用由片400制成的整体式土工格栅的特定服务应用，可使用上述五层的构造材料的多种组合。

[0091] 图15是与图14中所示的起始材料片400相关的三轴整体式土工格栅500的一部分的透视图。三轴整体式土工格栅500包括高度取向的条505和部分取向的接合点535。在对片400冲孔之后，片400的第一外层440和第二外层450已被拉伸并分别取向成条505和接合点535的第一外层540和第二外层550。类似地，片400的第一内层410和第二内层430已被拉伸并分别取向成条505和接合点535的第一内层510和第二内层530。并且，随着第一外层440和第二外层450以及第一内层410和第二内层430被拉伸并取向，中间层420也被拉伸并取向成条505和接合点535二者的中间层520。

[0092] 同样如上所述，本发明的一个可能的实施方案可以包括使用包含填充剂或填料的一个或更多个相对低成本的层。在整体式土工格栅的层中包含这样的填充剂或填料产生具有较厚(即较高)的轮廓的产品，这可能引起整体式土工格栅在某些服务应用中的性能提高。根据其中待采用整体式土工格栅的服务应用，这样的填充剂或填料可包括例如以下的一者或更多者：$CaCO_3$(碳酸钙)、滑石、$CaSiO_3$(钙硅石)、纳米填料、多壁碳纳米管(“MWCNT”)、单壁碳纳米管(“SWCNT”)、玻璃纤维和铝水合物。

[0093] 如较前所述，考虑了使用比高分子量聚烯烃和宽规格聚合物成本更低的一个或更多个聚合物层。在其中这样的较低成本的聚合物层还包含上述填充剂或填料的实施方案中，可能产生相对于使用例如聚丙烯层约20%的成本节约。

[0094] 当然，使用上述发泡层还可以产生具有较厚(即较高)的轮廓的产品，这还可能引起整体式土工格栅在某些服务应用中的性能提高。本发明的预期实施方案包括其中一个或更多个发泡层与包含填充剂或填料的一个或更多个层结合使用的那些。

[0095] 通常，本发明基于采用本文所述的共挤出技术和材料来改变和增强整体式土工格栅的某些物理、化学和/或机械特性，从而改善整体式土工格栅在其特定应用中的性能。

[0096] 前述内容仅被认为是对本发明原理的说明。此外，由于本领域技术人员可容易地想到许多修改和改变，因此不期望将本发明限制于所描述和示出的确切构造和操作。

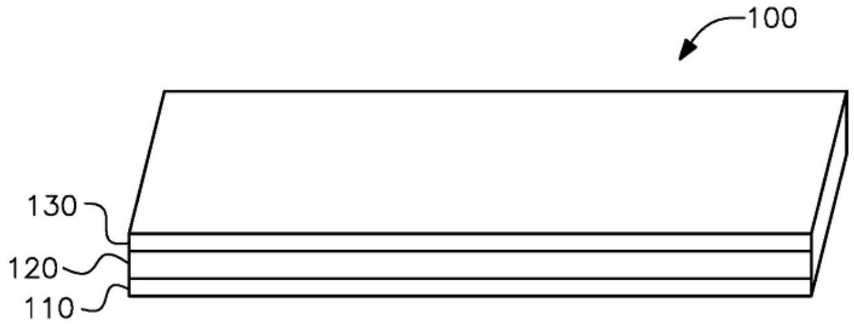


图1

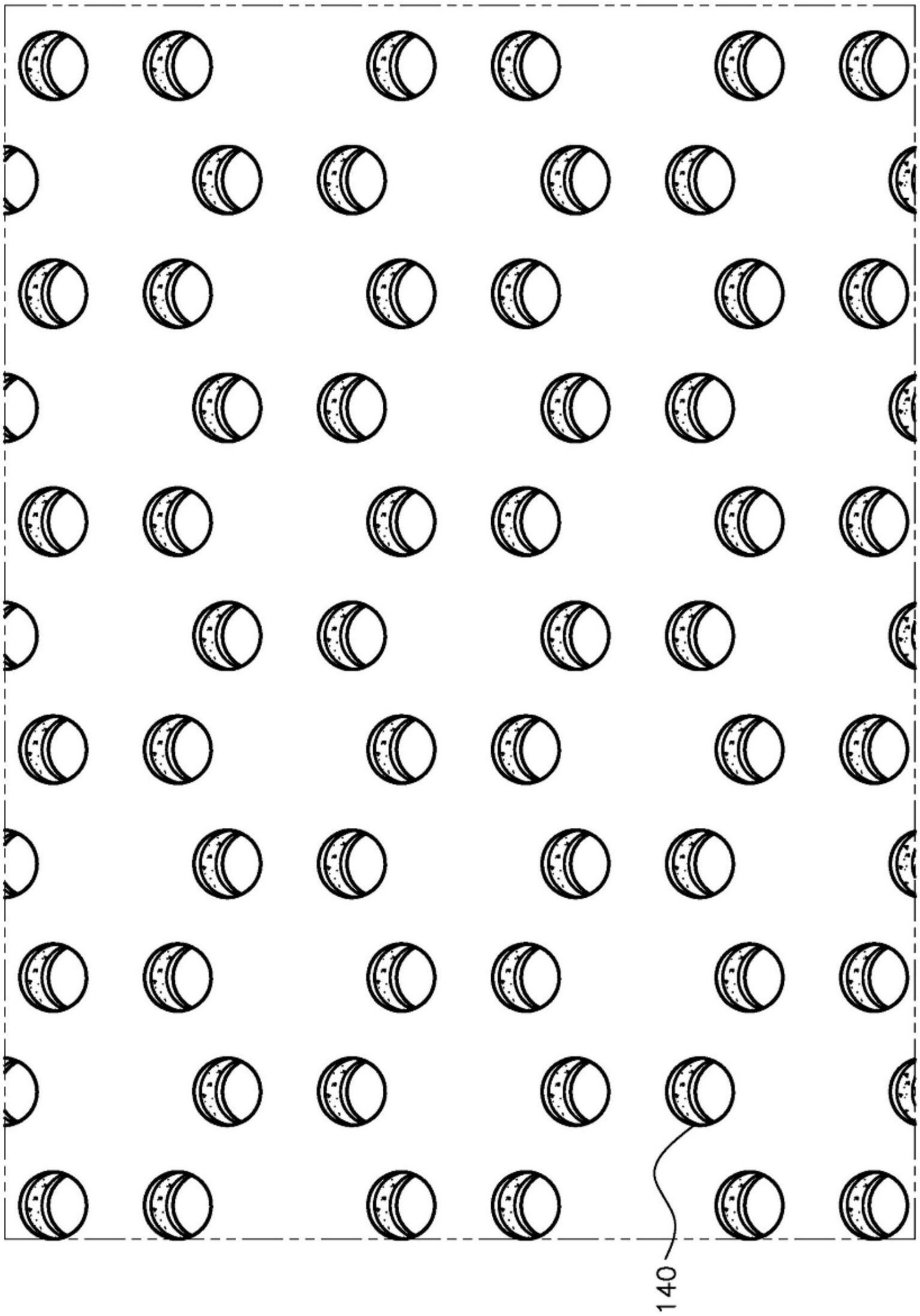


图2

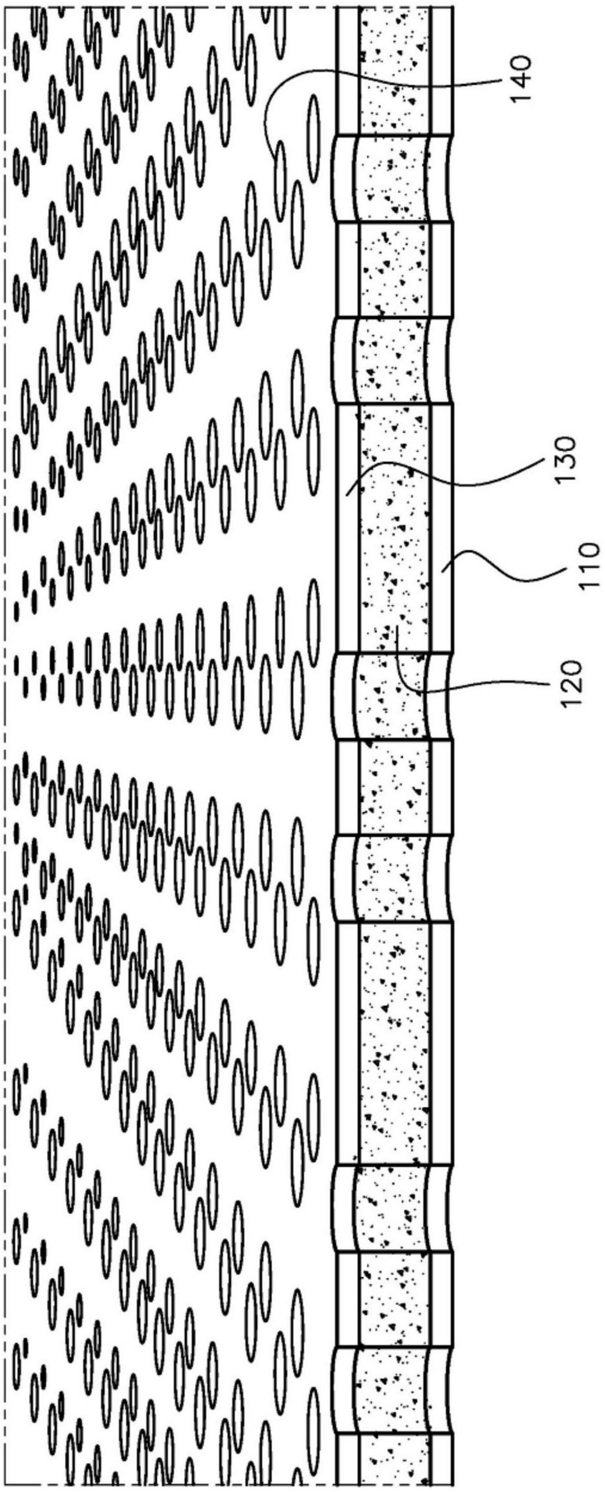


图3

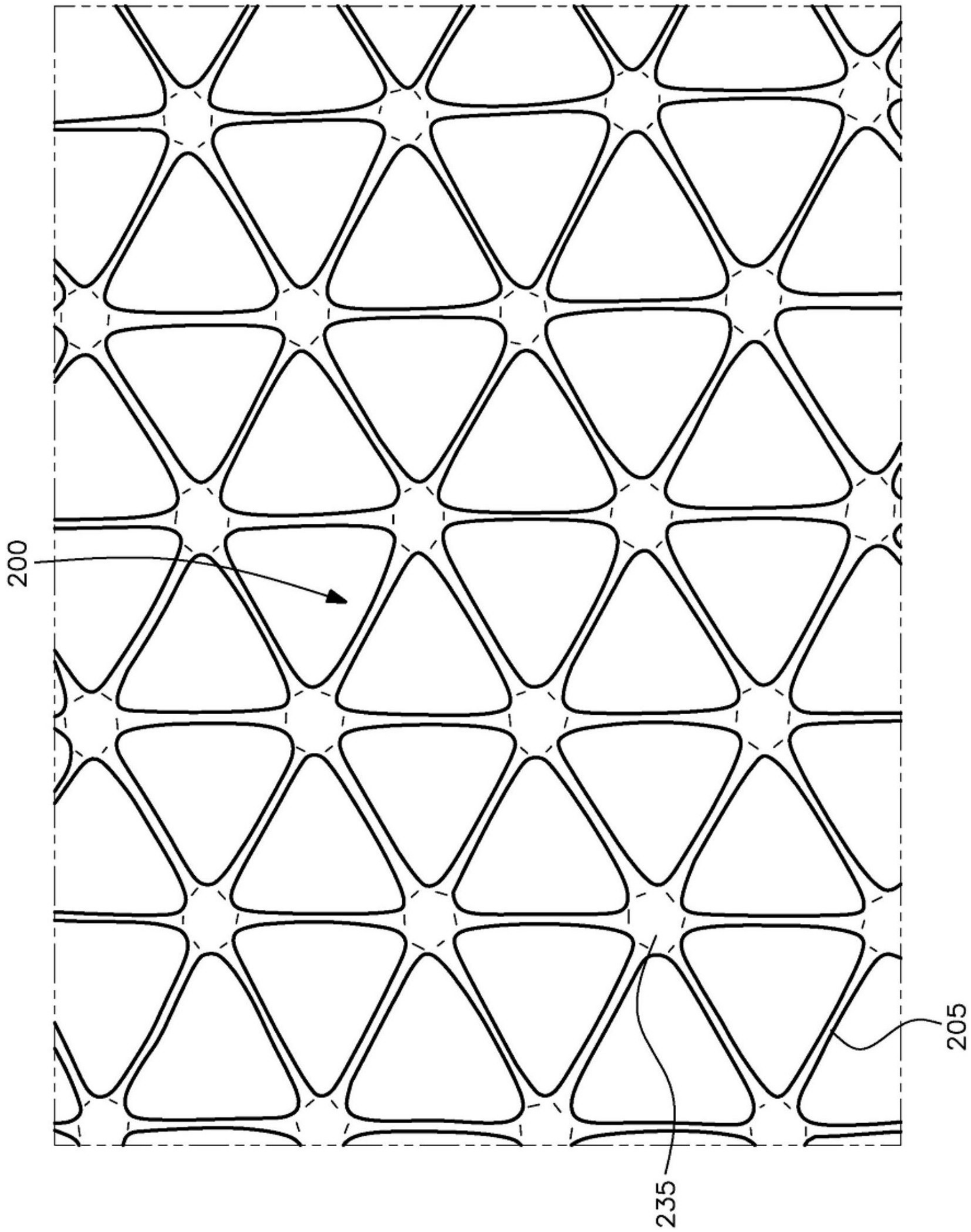


图4

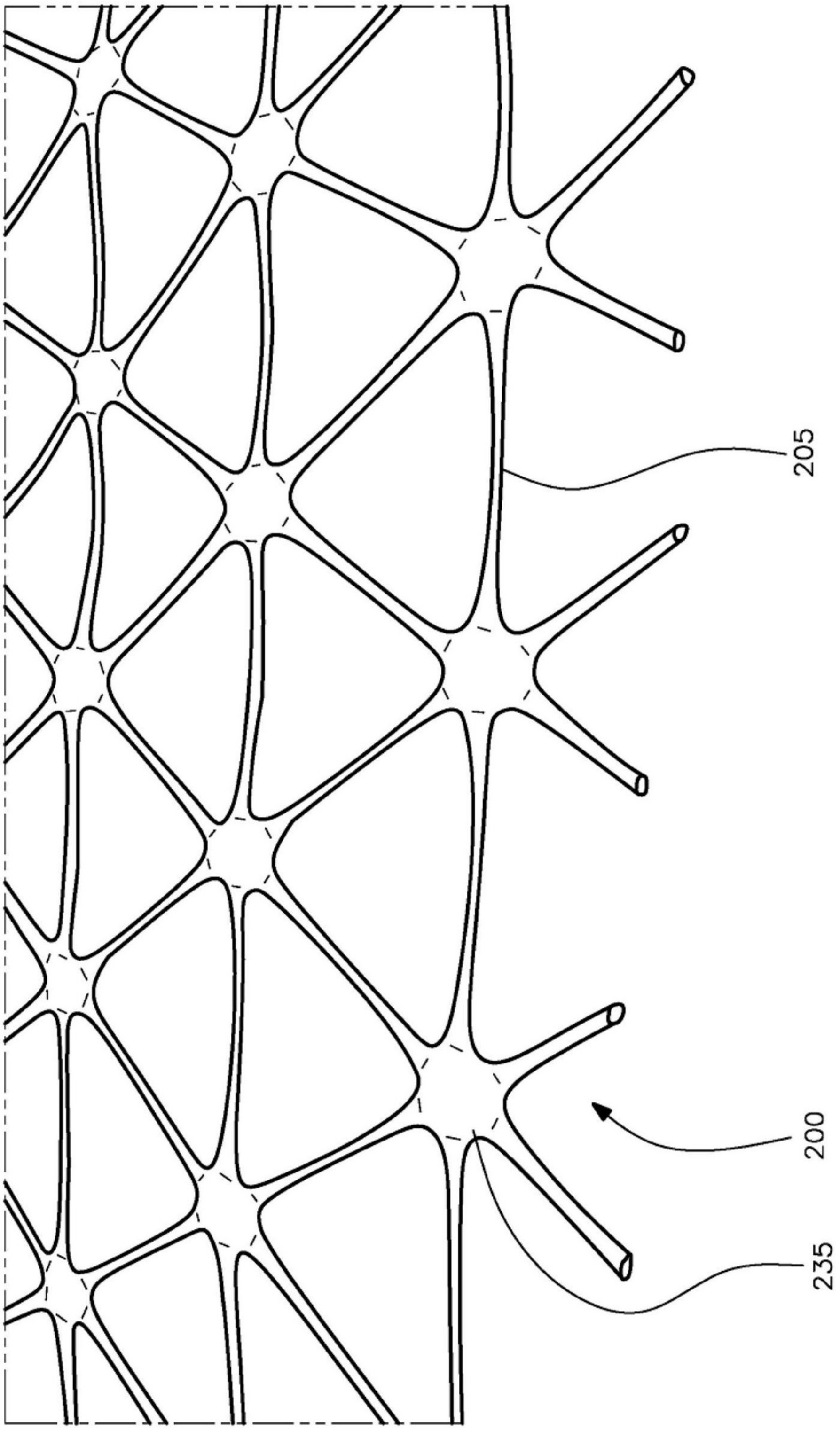


图5

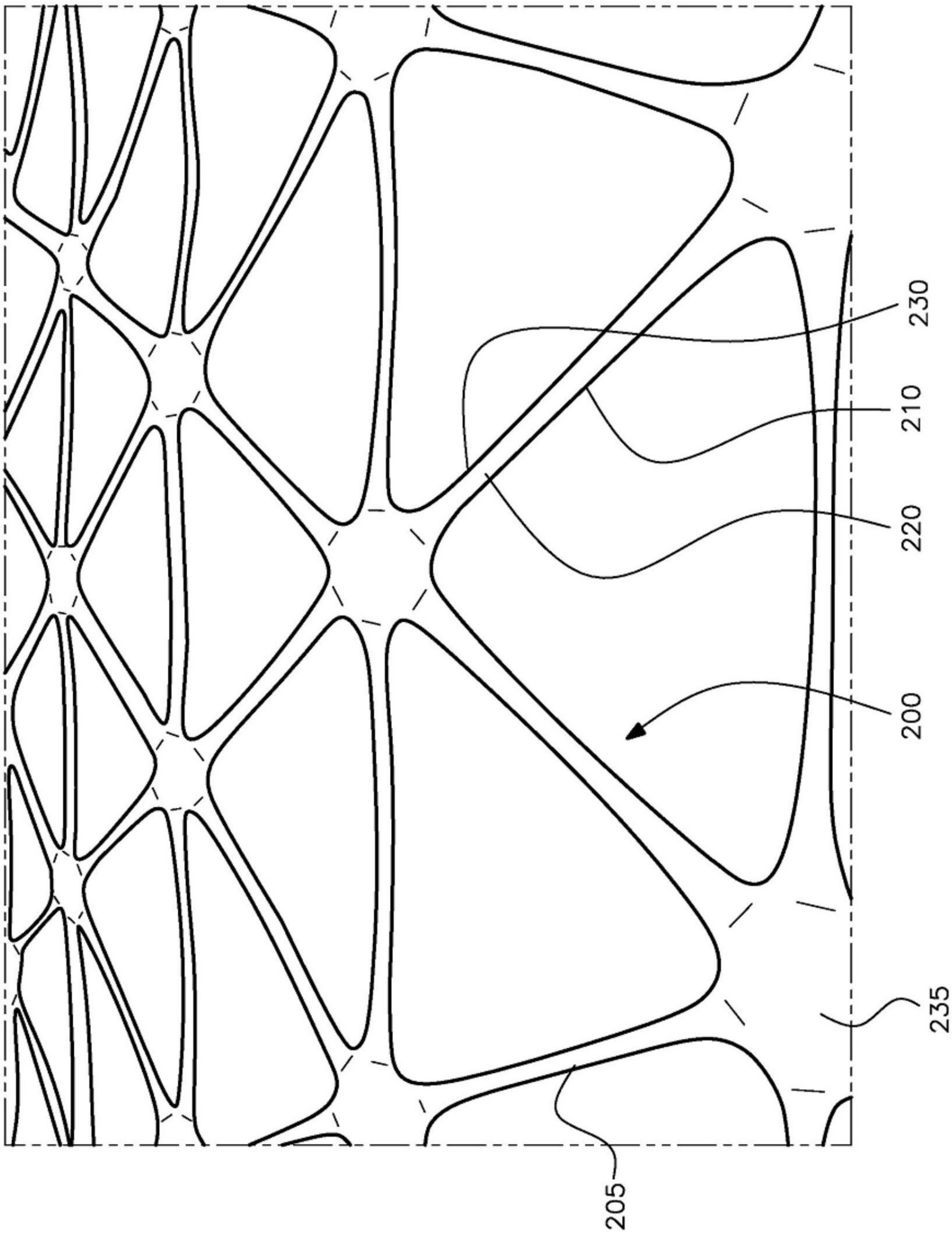


图6

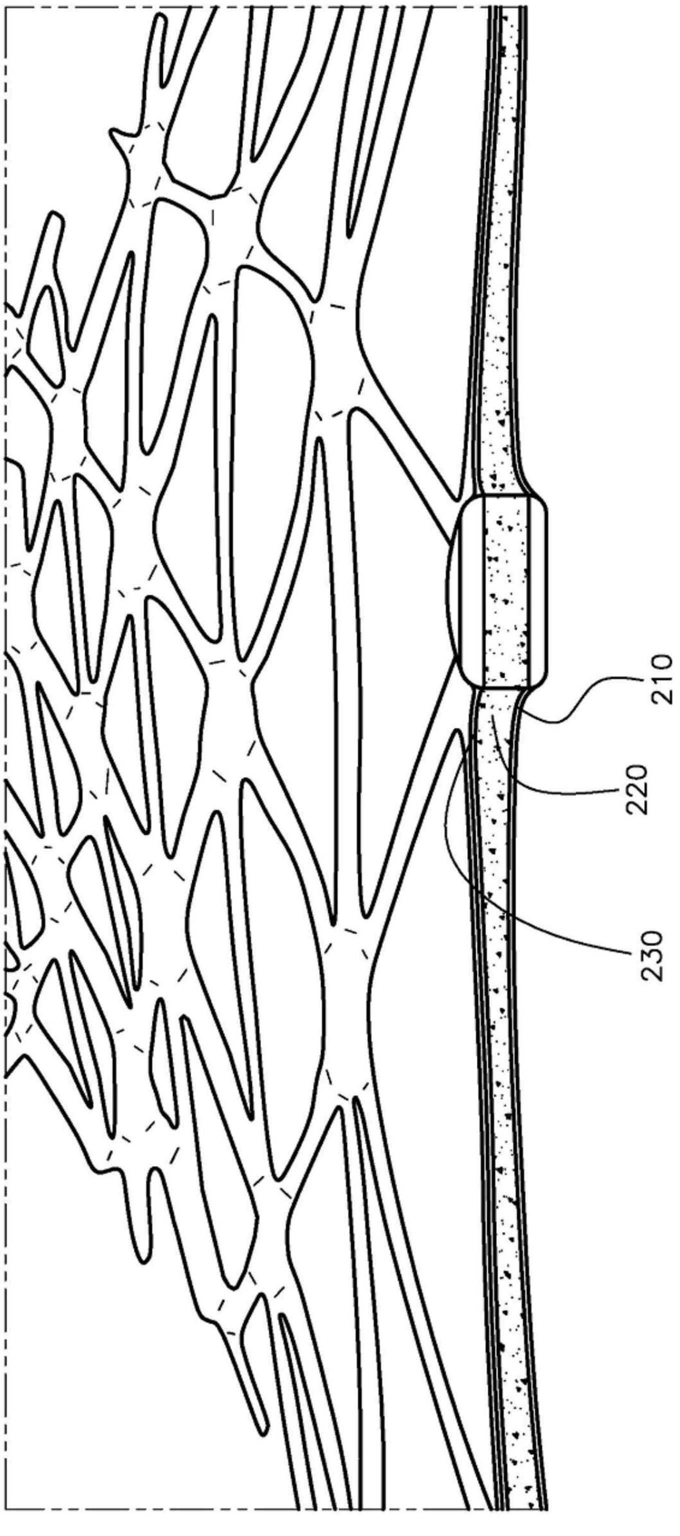


图7

施加的力矩 (cm-kg)	旋转（ 度 ）				旋转	孔稳定性模量 (cm-kg/度)		
样品 1	负载循环 1	负载循环 2	负载循环 3	负载循环 4	平均（ 度 ）	平均	初始	偏移
5	2.10	1.30	1.50	1.50	1.60	3.10	3.70	3.50
10	4.40	2.40	2.50	2.50	2.95	3.40		
15	6.40	3.50	3.60	3.50	4.25	3.50		
20	8.10	4.50	4.60	4.50	5.43	3.70		
25	9.90	5.90	5.80	5.80	6.85	3.60		

平均孔稳定性模量 (cm-kg/度)

图8

产品性质	测试方法	单位	TX160 (spec) MD	TX160 (spec) TD	TX160 (AVG QC) MD	TX160 (AVG QC) TD	32% BSR 4.6mm 片 MD	32% BSR 4.6mm 片 TD	50% BSR 4.6mm 片 MD	50% BSR 4.6mm 片 TD	原生实验室 MD	原生实验室 TD
特性												
炭黑	ASTM 4218	%	0.5		0.5		0.5		0.5		0.5	
单位重量	ASTM D3376	kg/m^2	0.223		0.220		0.210		0.214		0.203	
负载能力												
.5% 应变下的拉伸模量	ASTM D6637-01	磅/英尺 kN/m	750.0	750.0	900.0	950.0	1135.0	1050.0	1250.0	1200.0	1380.0	1300.0
2% 应变下的拉伸模量	ASTM D6637-01	磅/英尺 kN/m	na	na	260.0	280.0	344.5	200.0	355.0	355.0	420.5	390.0
5% 应变下的拉伸模量	ASTM D6637-01	磅/英尺 kN/m	na	na	196.0	210.0	254.0	136.0	256.0	254.0	311.8	284.0
结构完整性												
接合强度	GRI:GG2-87	磅/英尺 kN/m	21.4	18.6	12.6		15.9		17.6		17.0	
接合效率	GRI:GG2-87	%	93		92		103		119		104	
接合强度	GRI:GG2-01	磅 N	862	750	563		651		677		707	
抗弯刚度（总）	ASTM D5732-95 [9]	mg-cm	575,000		860,000		1,150,939					
孔稳定性（抗扭刚度）	Kinney-01	kg-cm/度	3.2		3.8		na		6.2		na	

图9

产品性质	测试方法	单位	TX140 (spec)		TX140 (AVG QC)		SN20140407 3.0mm 片		SN20140408 3.0mm 片		SN20140409 3.0mm 片	
负载能力			MD	TD	MD	TD	MD	TD	MD	TD	MD	TD
.5% 应变下的拉伸模量	ASTM D6637-01	磅/英尺 kN/m		220.0		300.0		280.0		320.0		300.0
2% 应变下的拉伸模量	ASTM D6637-01	磅/英尺 kN/m		na		230.0		255.0		245.0		250.0
5% 应变下的拉伸模量	ASTM D6637-01	磅/英尺 kN/m		na		176.0		190.0		182.0		180.0

结构完整性

抗弯刚度（总）	ASTM D5732-95 [9]	mg-cm	250,000		389,981							
孔稳定性（抗扭刚度）	Kinney-01	kg-cm/ 度	3.0				4.5		na		na	

图10

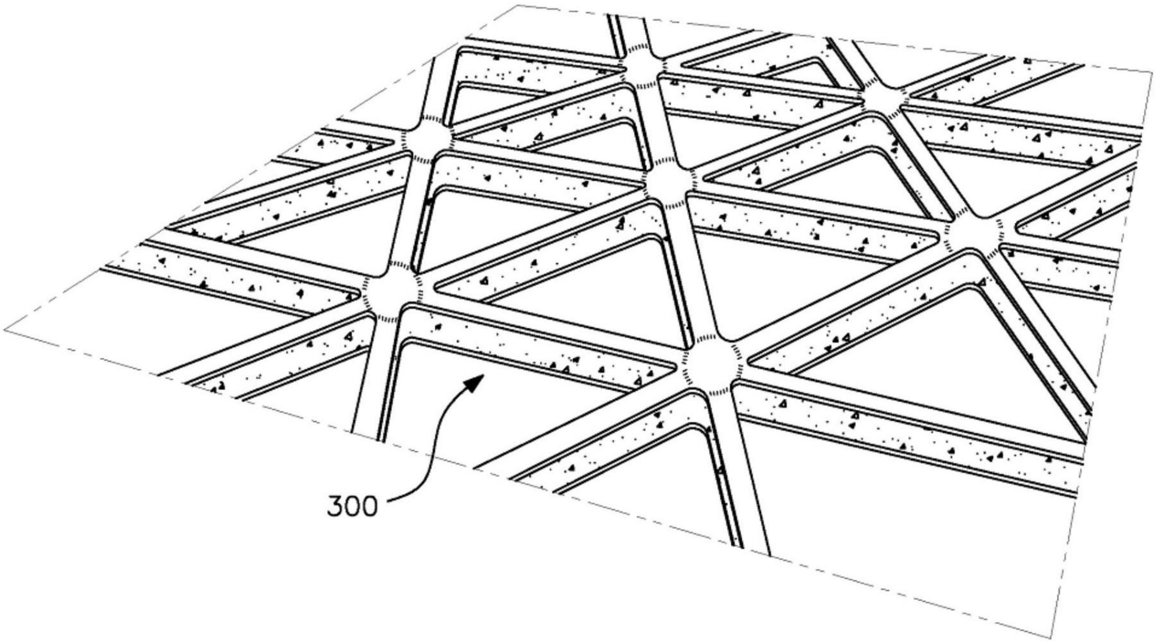


图11

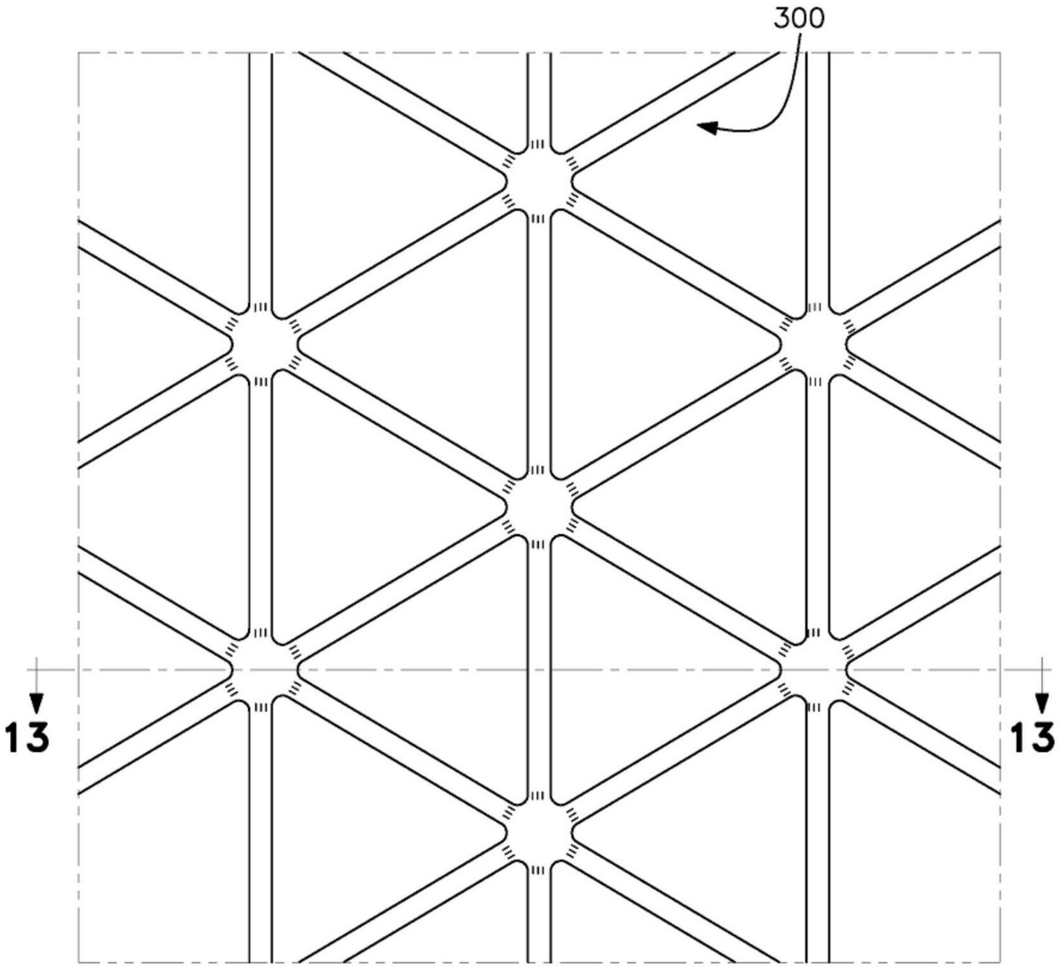


图12

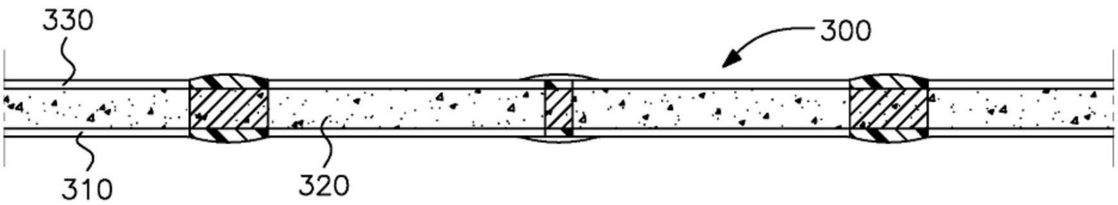


图13

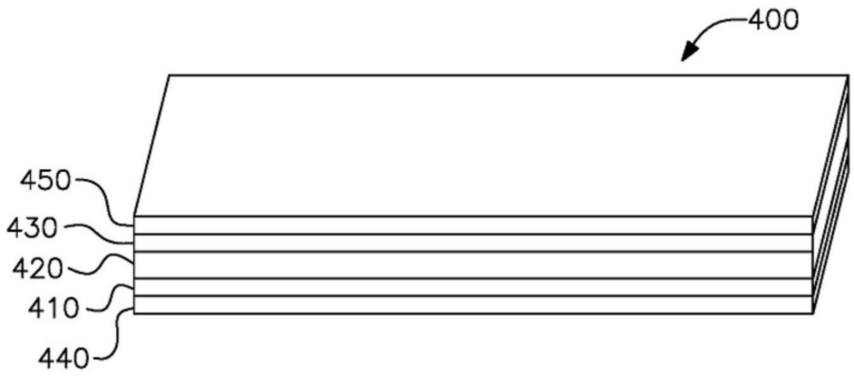


图14

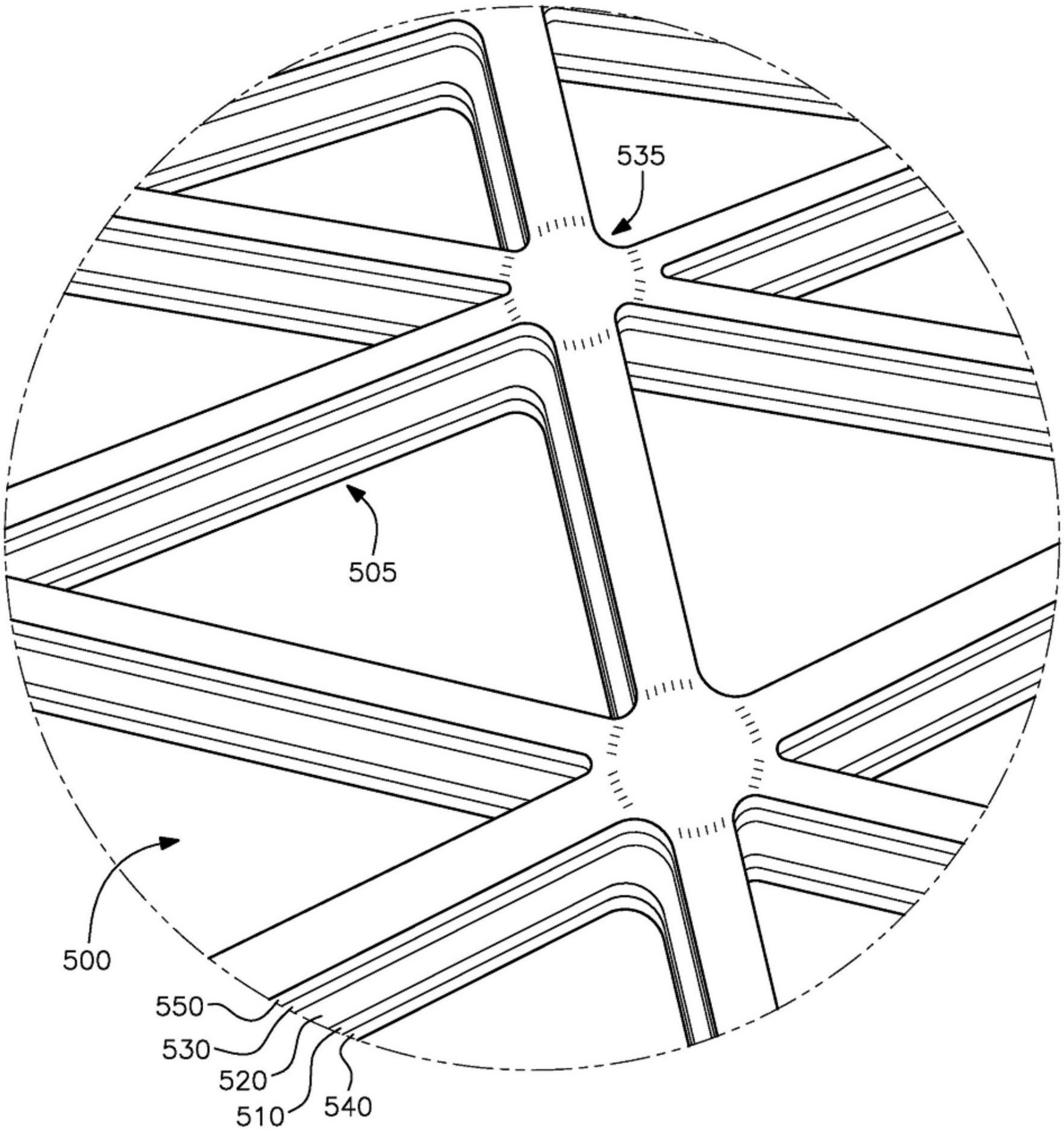


图15