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(54) **Title:** A CORE FOR A SANDWICH STRUCTURE

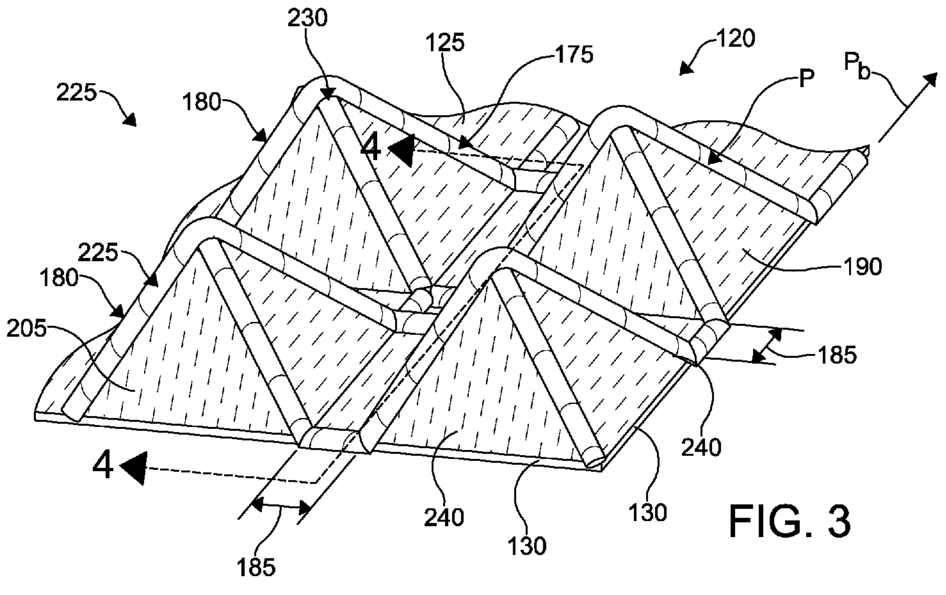

FIG. 3

(57) **Abstract:** A core formed by a process includes forming a yarn having a first fiber and a second fiber, providing the yarn in a pattern defining a base plane, and deforming the yarn at least normal to the base plane to form a three dimensional lattice incorporating the pattern. The first fiber is a polymer fiber and the second fiber is a reinforcing fiber.

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A CORE FOR A SANDWICH STRUCTURE

FIELD OF THE DISCLOSURE

[0001] This disclosure is directed to a core used in a sandwich structure. This disclosure is further directed to a core that includes a base material constructed from a polymer yarn formed into a three dimensional lattice.

BACKGROUND OF THE DISCLOSURE

[0002] Sandwich structures formed by applying skins to a core material, such as foam or honeycomb materials are used as structural components in applications that require lightweight materials with suitable strength. Example applications include vehicles used for mass transport such as aircraft or trains. In such applications, there is still a need for lighter materials to further improve the performance and efficiency of these vehicles. Specifically, there is a need for a core that can be used in a sandwich structure to provide suitable structural properties with less weight.

SUMMARY OF THE DISCLOSURE

[0003] According to an aspect of the disclosure, core is formed by a process comprising forming a yarn having a first fiber and a second fiber, wherein the first fiber is a polymer fiber and the second fiber is a reinforcing fiber; providing the yarn in a pattern defining a base plane, and deforming the yarn at least normal to the base plane to form a three dimensional lattice incorporating the pattern.

[0004] According to one aspect, a core includes a yarn having a first fiber and a second fiber, where the yarn is applied in a pattern on a carrier to form a base layer, and wherein the base layer is formed into a three dimensional lattice comprising the yarn. According to a further aspect, the first fiber and second fiber are a polymer fiber and reinforcing fiber. According to another aspect, the carrier is removable after the lattice is formed.

[0005] According to another aspect, a core includes the steps of forming a yarn from polymer fiber and reinforcing fiber, forming a two dimensional base layer with the yarn along a base plane, and deforming the base layer at least perpendicular to the plane at repeated intervals to form a three dimensional lattice.

[0006] According to another aspect, the step of forming the two dimensional base layer includes embroidering the base layer with the yarn.

[0007] According to another aspect, the step of deforming the base layer includes stitching the yarn. According to another aspect, the step of deforming the base layer includes pressing the two dimensional base layer with a press defining a pattern. Optionally, according to these aspects, the three dimensional lattice may be set by an additional step of heating the lattice, radiating the lattice with light or other waveforms, or applying a coating or other chemical setting agent.

[0008] According to another aspect, a core includes a lattice formed from at least one yarn, the lattice defining a base plane and having at least one raised area extending at least normal to the base plane, wherein the yarn includes a first fiber and a second fiber, wherein the first fiber and second fiber have different material properties.

[0009] Additional features, advantages, and aspects of the disclosure may be set forth or apparent from consideration of the following detailed description, drawings, and claims. Moreover, it is to be understood that both the foregoing summary of the disclosure and the following detailed description are exemplary and intended to provide further explanation without limiting the scope of the disclosure as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The accompanying drawings, which are included to provide a further understanding of the disclosure, are incorporated in and constitute a part of this specification, illustrate aspects of the disclosure and together with the detailed description serve to explain the principles of the disclosure. No attempt is made to show structural details of the disclosure in more detail than may be necessary for a fundamental understanding of the disclosure and the various ways in which it may be practiced. In the drawings:

[0011] Fig. 1 is a schematic view of a system according to one example depicting commingling of a first fiber and a second fiber to form a yarn.

[0012] Fig. 2 is a partially fragmented perspective view of a base layer including a yarn applied to a carrier according to the disclosure with a portion enlarged to show further details thereof.

[0013] Fig. 3 is a partially fragmented perspective view of a core according to one example of the disclosure.

[0014] Fig. 3A is a perspective view similar to Fig. 3 showing a core according to another example.

[0015] Fig. 4A is a sectional view showing formation of a raised area according to an example of the disclosure.

[0016] Fig. 4B is a view similar to Fig. 4A showing formation of a raised area according to an example of the disclosure.

[0017] FIG. 5 is flow diagram depicting the steps of forming a lattice in a core according to an example of the disclosure.

[0018] Fig. 6 is a flow diagram depicting steps of forming a lattice in a core according to an example of the disclosure.

[0019] Fig. 7 is schematic side view depicting a manufacturing process for forming a lattice according to an example of the disclosure.

[0020] Fig. 8 is a schematic view similar to Fig. 7 depicting application of heat to the lattice during formation according to an example of the disclosure.

[0021] Fig. 9 is a schematic view similar to Fig. 7 depicting an optional step of setting the lattice after it is formed according to an example of the disclosure.

[0022] Fig. 10 is a fragmented side view depicting attachment of a first and a second structure to the lattice in a core according to an example of the disclosure.

[0023] Fig. 11 is a fragmented side view of a core according to an example of the disclosure having first and second structures attached to a lattice.

[0024] Fig. 12 is a perspective view depicting an article formed from a core according to an example of the disclosure.

DETAILED DESCRIPTION OF THE DISCLOSURE

[0025] The aspects of the disclosure and the various features and advantageous details thereof are explained more fully with reference to the non-limiting aspects and examples that are described and/or illustrated in the accompanying drawings and detailed in the following description. It should be noted that the features illustrated in the drawings are not necessarily drawn to scale, and features of one aspect may be employed with other aspects as the skilled artisan would recognize, even if not explicitly stated herein. Descriptions of well-known components and processing techniques may be omitted so as to not unnecessarily obscure the aspects of the disclosure. The examples used herein are intended merely to facilitate an understanding of ways in which the disclosure may be practiced and to further enable those of skill in the art to practice the aspects of the disclosure. Accordingly, the examples and aspects herein should not be construed as limiting the scope of the disclosure, which is defined solely by the appended claims and applicable law. Moreover, it is noted that like reference numerals represent similar parts throughout the several views of the drawings.

[0026] The disclosure is directed to a core. For example, a core includes a base layer formed from a yarn with at least one of a polymer fiber and a reinforcing fiber attached to a carrier, as by stitching or embroidering. The base layer is formed into a three dimensional pattern to form a core having a lattice structure. Optionally, carrier may be removed during or after formation of the lattice to further reduce the weight of the core.

[0027] With reference to FIG. 1, a system for forming a core according to an example is generally indicated by the number 100 in Fig. 1. System 100 generally provides one or more fibers 110 formed into a yarn 115. When using multiple fibers, fibers 110 may be commingled (at 140) to form a yarn 115 that is applied to a carrier 125 in a pattern P to form a base layer (Fig. 2) discussed more completely below. The use of a fiber based structure provides a weight savings over solid material structures of similar thickness resulting from spaces within the base layer resulting from the fiber form. As discussed below, the base layer may be formed into a three dimensional lattice and the carrier material removed to leave a skeletal lattice structure. As a result, an extremely lightweight lattice may be formed for use as a core.

[0028] With reference to FIG. 2, a commingled yarn 115 comprising at least a first fiber 145 and a second fiber 150 bundled together may be applied to a carrier 125 to form a base layer 120 having a lattice pattern P. Carrier 125 may have a generally two dimensional planar form providing a thin sheet of material on which yarn 115 is provided. Carrier 125 may be any material suitable for supporting yarn 115 during formation of the core including but not limited to paper or other pulp materials, woven and non-woven materials, plastics, and combinations thereof. In the example shown, carrier 125 is a thermoplastic material.

[0029] Various fibers may be used to form yarn 115 including commingled thermoplastic yarns. Commingled thermoplastic yarns can include thermoplastic resin fibers and reinforcing fibers. Such fibers can lie adjacent to one another, occasionally abutting one another. The fibers can be dispersed individually throughout the yarn 115. The fibers can be dispersed in bundles throughout the commingled yarn. Bundles can include fibers of thermoplastic material, fibers of reinforcing material, or a combination comprising at least one of the foregoing.

As used herein bundle can refer to a grouping of more than one fiber of the same material or a grouping of more than one fiber of different materials.

[0030] The yarn 115 can be attached to a carrier 125 in a specific pattern and can substantially align the orientation of reinforcing fibers within the composite part. Where "substantially", as in "substantially align", can include variations due to the undulating nature of sewing a yarn, can allow for turning direction to create multiple passes throughout a pattern, can allow for turning direction of yarn to build up width or thickness of a part, and/or can allow for natural splaying of reinforcing fibers.

[0031] As shown in FIG. 1, more than one fiber 110 may be combined to form a yarn 115 at 140. For example, a first fiber 145 and a second fiber 150 may be woven, commingled, or otherwise joined together to form a yarn 115. Likewise, first fiber 145 may be impregnated with second fiber 150 to form yarn 115. First and second fibers 145 and 150 generally differ in some respect including but not limited to material properties, geometrical structure or cross section, color, texture, or other characteristic that the designer wants to commingle. In one example, first fiber 145 is a polymer fiber and second fiber 150 is a reinforcing fiber. In this example, reinforcing fiber has material property that is different than first fiber in that it is of relatively greater strength or stiffness than the polymer fiber. Additional fibers may be commingled to form yarn 115 or multiple yarns 115 may be used in forming base layer 120. For simplicity, the description will continue with reference to a yarn 115 formed from two fibers 145,150. As a further option, yarn 115 may be further reinforced or other properties may be imbued to the yarn 115 during the commingling of fibers or by a post-processing technique. For example, as the yarn 115 is formed, reinforcing fibers or structures may be impregnated with or applied to one or more of the fibers or the yarn. After the yarn is formed, a similar step of applying additional reinforcing or other structures to the yarn may be employed, or the yarn may be chemically, heat or light treated.

[0032] Commingled yarns can be produced in a variety of ways. Tows (e.g., untwisted bundles of fibers) of reinforcing fibers and thermoplastic resin fibers can be formed into a commingled yarn, by air entanglement, which interlaces the fiber bundles. Tows of reinforcing fibers and thermoplastic resin fibers can be twisted, spun, wrapped, mechanically intertwined, or a combination comprising at least one of the foregoing to form a commingled yarn, for example, as can be done in rope-making. Commingled yarn can include stretch broken fibers, where the individual fibers have a specific length that is shorter than the length of the yarn. Commingled yarn can include a wrapping fiber that wrap around another fiber. Commingled yarn can include wrapping fibers that wrap around other fibers. Wrapping fibers can include reinforcing fibers, thermoplastic resin fibers, or a combination comprising at least one of the foregoing.

[0033] In commingled yarns, the thermoplastic resin fibers and reinforcing fibers can be randomly distributed, e.g., the location the fibers throughout the cross-sectional area of the yarn is not predetermined or particularly selected, the location of the fibers can be the result of the manufacturing process of the yarn. The thermoplastic resin fibers can be uniformly distributed throughout the cross-sectional area of the yarn, e.g., the thermoplastic resin fibers can be evenly spaced apart from one another throughout the cross-sectional area of the yarn where the distance between any two thermoplastic resin fibers is constant throughout the cross-sectional area of the yarn. The thermoplastic resin fibers can be particularly distributed throughout the cross-sectional area of the yarn, e.g., non-random where the location of thermoplastic resin fibers can be selected or predetermined during manufacturing of the yarn. A particular yarn distribution can be used to fine tune thermoplastic flow throughout a composite part during consolidation. The reinforcing fibers can be in abutting contact with the thermoplastic resin fibers throughout the yarn. The cross-sectional distribution, of resin fibers and reinforcing fibers, can vary throughout the length of the commingled yarn as measured in the longitudinal direction.

[0034] The reinforcing fibers can be stiffer than the thermoplastic resin fibers. The reinforcing fibers can have a higher tensile strength (e.g., tenacity) than the thermoplastic resin fibers. The reinforcing fibers within commingled yarns can include carbon fiber, glass fiber, aramid fiber, basalt fiber, quartz fiber, boron fiber, cellulose fiber, natural fiber, liquid crystal polymer fiber, high tenacity polymer fiber (e.g., polypropylene, polyethylene, poly(hexano-6-lactam), poly[imino(1,6-dioxohexamethylene) imnohexamethylene]), or a combination of at least one of the foregoing.

[0035] The thermoplastic resin fiber fibers can include polycarbonates, polyetherimides (PEI), polyetheretherketones (PEEK), polyetherketoneketone (PEKK), polyetherketone (PEK), polypropylenes, polyethylenes, including polytetrafluoroethylene (PTFE), polystyrenes, polyvinyls, including polyvinyl chlorides (PVC), polyethylene terephthalates, polybutylene terephthalates (PBT), polyoxymethylene (POM), poly(p-phenylene ether) (PPE), acetals, acrylics, nylons, thermoplastic polyurethanes, polyacetals, polyphenylene sulfides, cycloolefins, thermotropic polyesters, acrylonitrile butadiene styrene (ABS), an ionomer thereof, a copolymer thereof, or a combination comprising at least one of the foregoing. In the example shown, yarn 115 comprises PEI fiber commingled with at least one of a carbon, glass or aramid reinforcing fiber.

[0036] The commingled yarns can include a mixture of thermoplastic resin fibers and reinforcing fibers. A commingled yarn can include a total of 2 to 100,000 fibers, for example, 1,000 to 50,000 fibers, or, 3,000 to 50,000 fibers.

[0037] A reinforcing fiber can have a thickness of 1 micrometer (μm) to 50 μm (as measured along the longest linear dimension spanning the cross-section of the fiber in the t-x plane in the attached figures), for example, 2 μm to 30 μm, or, 5 μm to 20 μm.

[0038] A thermoplastic resin fiber can have a thickness of 1 μm to 100 μm (as measured along the longest linear dimension spanning the cross-section of the fiber in the t-x plane in the attached figures), for example, 5 μm to 50 μm, 5 μm to 25 μm.

[0039] A commingled yarn can have a thickness of 0.1 millimeter (mm) to 20 mm, for example, 0.2 mm to 5 mm, or 0.5 mm to 3 mm.

[0040] The thermoplastic resin fibers and reinforcing fibers can have any cross-sectional shape along their length. The cross-sectional shape of a fiber can change along the length of the fiber. For example, the cross-sectional shape of a thermoplastic resin and/or a reinforcing fiber can be circular, oval, or any simple closed polygonal shape (e.g., cyclic, equiangular, equilateral, tangential, and rectilinear polygons, further including triangular, quadrangular, pentagonal, hexagonal, heptagonal, octagonal, star shaped, and the like) with straight or curved edges. The circular cross-sections shown in the figures are for simplicity of illustration and should not be considered limiting.

[0041] Similarly, a bundle of fibers can have any cross-sectional shape. Void space can be formed between fibers within the bundle, due at least in part, to the cross-sectional shapes of the individual fibers, which combine to form a bundle. For example, the cross-sectional shape of a thermoplastic resin or reinforcing fiber bundle can be circular, oval, or any simple closed polygonal shape (e.g., cyclic, equiangular, equilateral, tangential, and rectilinear polygons, further including triangular, quadrangular, pentagonal, hexagonal, heptagonal, octagonal, star shaped, and the like) with straight or curved edges.

[0042] The commingled yarn can have any cross-sectional shape. Void space can be formed between fibers within the commingled yarn, due at least in part, to the cross-sectional shapes of the individual fibers, which combine to form the commingled yarn. For example, the cross-sectional shape of a commingled yarn can be circular, oval, or any simple closed polygonal shape (e.g., cyclic, equiangular, equilateral, tangential, and rectilinear polygons, further including triangular, quadrangular, pentagonal, hexagonal, heptagonal, octagonal, star shaped, and the like) with straight or curved edges.

[0043] The commingled yarn can have 5 wt% (weight percent) to 95 wt% reinforcing fiber material, for example, 40 wt% to 60 wt%, or, 50 wt% reinforcing fiber material, where the balance of the yarn can be thermoplastic resin material.

For example, the yarn can be made of 50 wt% reinforcing fibers, and 50 wt% thermoplastic resin fibers. The reinforcing fiber material can have a lower specific density (weight per unit volume) than the thermoplastic resin which can result in higher volume fractions of reinforcing material in the commingled yarn, when the weight percentages of the reinforcing material and thermoplastic material are equal.

[0044] When forming a pattern P on carrier 125, a yarn roving or filament can be attached to a carrier material to hold the yarn in place as the pattern P is formed (Fig. 2). The carrier 125 can include thermoplastic resin, reinforcing fiber or a combination including at least one of the foregoing. The carrier 125 can be a film, woven or nonwoven sheet, a matrix-compatible foil, and the like. With reference to FIG. 2, a woven carrier 125 is shown. As discussed, yarn 115 attached to carrier 125 may be a single yarn that is continuously applied to form pattern P or separate segments of yarn 115 may be attached.

[0045] A thermoplastic resin used as a carrier material can be the same thermoplastic resin as used in yarn 115. A thermoplastic resin used as a carrier material can be a different thermoplastic resin than the thermoplastic resin of the yarn. A carrier 125 having the same thermoplastic resin as yarn 115 can eliminate compatibility issues associated with different resins. A carrier material having the same thermoplastic resin as the resin matrix of the composite part can eliminate compatibility issues associated with different resins, such as processing temperature, chemical compatibility, decomposition temperature, other physical properties, and the like. A dissimilar carrier material may be useful in creating differences in properties between the yarn formed pattern and carrier that facilitate removal of carrier 125 after the desired three dimensional core is formed, as discussed more completely below.

[0046] With reference to FIGS. 2 and 3, a base layer 120 is a generally two dimensional structure that includes a carrier 125 with yarn 115 attached thereto in a desired pattern P. Base layer 120 is used as a precursor or pre-form for the finished core. In forming base layer 120, the underlying carrier 125 may be any suitable material, as discussed above, and be provided in any configuration suitable for the desired pattern P to produce the finished core. To that end, carrier 125 may have at least one edge or border 130 at an outer extremity thereof. The border 130 may have any shape or profile including geometric shapes (square, rectangle, circular etc.) or custom shapes created for particular applications or particular design choices.

[0047] In the example shown in FIG. 2, base layer 120 includes a woven carrier 125, which may be formed using various textile forming techniques. Carrier 125, shown, has woven threads 133 in the warp and weft directions defining weave spaces 135 there between. It will be understood that spaces may be effectively eliminated when using a very tight weave. A polymer film or paper carrier 125 could be used to the same effect in the example shown. At least one yarn 115 is attached to carrier 125 to form a pattern P. Pattern P may be any pattern and is limited only by design choice and the desired three dimensional shape. For example, to form a lattice having a pyramid shape, yarn 115 is attached to carrier 125 in a pattern P that resembles an X. The X shape may be repeated as often as desired to produce a series of pyramids when the base layer is formed into a three dimensional shape as discussed below. While a repeating pattern P of uniform X-shapes is shown, it will be understood that pattern P may include multiple yarn shapes that repeat in alternating fashion or shapes that do not repeat when forming base layer 120.

[0048] In forming the base layer 120, the yarn 115 can be attached to a carrier material without a separate fixing, or holding, thread T. A stitching operation, for stitching yarn 115 directly to a carrier 125, can be performed by embroidering machines or sewing machines. A yarn 115 can be stitched directly to a carrier 125 with a single stitching head or multiple heads may be used to apply multiple yarns 115 in pattern P.

[0049] The fixing thread T can be made of a thermoplastic resin or reinforcing fiber. A separate thermoplastic thread can be used to augment the amount of plastic in specific areas of the pattern P or help to achieve the desired plastic flow, help to achieve a specific ratio of thermoplastic to reinforcing fibers in a selected location or adjust resin flow during consolidation, such that the reinforcing fibers are sufficiently wet out to achieve the desired properties in the finished core.

[0050] Alternately, yarn 115 can be attached to carrier 125 by, holding the yarn in place periodically by spot-melting the yarn to form a weld at W, such as with a laser, with an ultrasonic welder or by using heat-staking. Commingled yarns can also be attached to other commingled yarn already attached to the carrier material in a similar fashion, e.g., via sewing, spot-melting, ultrasonic welding, adhesive deposition, heat-staking, or a combination thereof. In this way, the preform can be built-up, increasing the thickness in a direction perpendicular to the surface of the carrier material. When the base layer 120 is built up with more than one layer of commingled yarn, the thickness of the preform (perpendicular the surface of the carrier material) can be less than or equal to 50 mm, for example, 1 mm to 15 mm, or, 1 mm to 8 mm, without compromising the integrity of the commingled fibers (e.g., without breaking fibers within the commingled yarn).

[0051] The pattern P can be chosen such that the direction of the reinforcing fibers can be substantially aligned with one another or substantially aligned parallel to a selected force flux for example, a steady state force flux that is expected to be applied to the finished core. Once the commingled yarn pattern is attached to a carrier material, any amount of excess carrier material can be removed by a cutting operation. In this case, the cutting operation does not require cutting of the reinforcing fibers, which have been attached to the carrier material as a substantially continuous yarn. Base layers 120 formed in this manner can be fabricated in a single stitching operation.

[0052] With reference to FIG. 3, once base layer 120 is formed, it is processed into a three dimensional structure, generally indicated by the number 175. Three dimensional structure 175 may generally have a plural raised areas 180 formed at intervals 185 relative to each other defining a pattern P. Raised areas 180 may be evenly spaced or otherwise formed at regular intervals 185 (FIGS. 3 and 7) or irregular spacing or intervals may be used. The three dimensional structure might also include depressions or lowered areas that extend below the plane P_b formed by base layer 120. The raised area 180 and lowered areas may be formed in any known manner. According to one example such areas are formed by a press, mold, or other mechanical deformation of base layer 120.

[0053] According to an example, raised areas 180 are formed in base layer 120 such that each raised area includes an outer surface 205 that defines a raised profile or shape 210, and an inner surface 215 that defines a hollow or void 220 (FIGS. 3A and 4) to form a lattice structure or simply a lattice, generally indicated by the number 225.

[0054] With reference to FIG. 3, lattice 225 may include raised areas 180 formed at regular intervals 185 within base layer 120. As best seen in FIG. 3B, raised areas 180 have an upper extremity 230 formed on outer surface 205 located at the furthest point outward of the plane P_b of base layer 120. Upper extremity 230 includes a surface 235 that may be formed to be substantially parallel to base layer plane Pb to facilitate attachment of skins or other structures to the lattice 225. Raised areas 180 may have any shape 210. In the example shown, raised areas 180 are provided with a pyramid shape with four generally triangular sides 240 extending upward and inward from base plane P_b and terminating at surface 235.

[0055] In the example shown, the three dimensional structure includes a pattern P of raised areas formed in a substantially grid like pattern 190. The raised areas within the pattern are formed at regular intervals 185 and spaced equally from each other on all sides. A 2x2 grid is shown as one example, but is not limiting as the grid may be expanded to encompass any number of raised areas suitable for the size of the lattice 225 being produced. The system 100 shown in the drawings is not limited to the dimensions and proportions shown. It will be understood that length, width, and depth of the lattice 225 may be varied from the one shown in the drawings.

[0056] As discussed above, raised areas 180 include a surface 235 that extends generally parallel to the base plane Pb. In the given example, the base 245 of each of these structures lies in and defines base plane Pb once the three dimensional structure is formed. In the example shown, the bases 245 of the several raised areas 180 shown are formed substantially within the plane to present a generally uniform surface, generally indicated by 250, to facilitate attachment of skins or other structures to the core 100.

[0057] Base layer 120 can be consolidated to form core 100 using a compaction/compression processes, e.g., pressing or molding. For example, base layer 120 (and additional layers if present) can be placed into a mold having a shape complimenting the shape of the finished core 100. The mold or press mechanically deforms base layer 120 to form the three dimensional shape of core 100. As needed, base layer 120 can then be heated to a specified temperature to reduce the viscosity of the resin within base layer 120. Once the temperature reaches the glass transition temperature, or melting temperature, of the thermoplastic resin, the thermoplastic resin begins to soften, melt, and move.

[0058] The softened polymer resin moves, or flows, into voids between reinforcing filaments within the preform and thus surrounds and bonds to the surfaces of the reinforcing filaments. In this way, the finished core includes reinforcing filaments encapsulated in a thermoplastic resin matrix. The three dimensional structure can be compacted, e.g., pressed, to a specified pressure to squeeze out air that may be entrapped in the part, thus eliminating void space. The pressure and temperature of the preform can be maintained for a selected time, at least in part, to ensure sufficient saturation and bonding of the resin to the reinforcing filaments and part integration. The temperature can then be reduced while the compaction pressure is maintained to hold the shape of the finished core as the thermoplastic resin cools and solidifies. Once the preform temperature is reduced below the glass transition temperature, or melting temperature, of the thermoplastic resin, the part can be removed or ejected from the compaction device, e.g., mold, and the part can be cooled to room temperature.

[0059] Once the core 100 has been formed, the part can be processed post-consolidation, or finish-processed, to form a finished core. Post-consolidation processing operations can include removing material, and/or reforming the part chemically, mechanically, and/or thermally, for example, post-consolidation processing can include abrasive blasting, breaking, buffing, burnishing, cutting, drilling, etching, eroding, grinding, indenting, machining, marking, polishing, sanding, scoring, shaping, threading, trimming, tumbling, vibrating, and/ or otherwise creating surface treatments, or a combination including at least one of the foregoing. Post-consolidation processing operations can include adding material to the part, for example, post-consolidation processing can include adding (i.e., applying) coatings, as in sealers, glazes, paints, functional layers, markings, and/or other surface additives to the part, or a combination of at least one of the foregoing. Types of coatings can include abrasion resistant, adhesive, antimicrobial, catalytic, decorative, electrically or thermally conductive, electrically or thermally non-conductive, light sensitive, non-adhesive, optical, primers, ultra-violet protective, waterproof, or a combination comprising at least one of the foregoing.

[0060] With reference to FIG. 3A, the weight of three dimensional structure shown in FIG. 3 may be reduced by removing carrier 125 from base 120 after the pattern P has been applied. For example, carrier 125 may be removed during formation of three dimensional lattice 225 or after lattice 225 is formed through application of heat to melt away carrier 125 or by application of a solvent to dissolve carrier 125 or wash it away to leave the skeletal lattice (FIG. 3A) formed by the pattern P of yarn 115. During processing areas of carrier material that lack yarn 115 may be removed by taking advantage of differences in the glass transition temperature of the materials such that the carrier material surrounding the yarn reinforced areas melts away and may be drained from mold leaving the yarn reinforced pattern P to be formed into the finished lattice that has a skeletal form lacking carrier material in the spaces between yarn sections. Alternatively, carrier may be removed during a post-mold process. With references to FIGS. 3 and 3A, FIG. 3 shows a lattice 225 where carrier 125 is present and FIG. 3A shows the carrier 125 removed. In FIG. 3, carrier 125 extends between structures formed by yarn 115 at 195 and may also underlie yarn 115 or become intermingled with yarn 115 during forming of the three dimensional structure. As discussed, different removal techniques may be used to remove carrier 125. Depending on the technique, carrier that is intermingled with yarn 115 may be removed or remain.

[0061] With reference to FIGS. 1, 5 and 6-9, a method of manufacturing a system 100 according to an example is shown. At a step 400, a yarn is formed. With reference to FIG. 1, yarn 115 may be formed from a single fiber or multiple fibers 110, as discussed above. In the example shown, a first fiber 145 and a second fiber 150 are commingled at a yarn former 140 to form yarn 115. First fiber is a polymer fiber and second fiber is a reinforcing fiber having different properties than first fiber. The method may include the step of forming the fibers as well, or fibers may be obtained from a separate source and commingled. In the example shown, fibers 145,150 are shown provided on spools 155,160 but other fiber delivery systems may be used. The step of commingling 405 may include mechanically joining the fibers for example by spinning, braiding, twisting; chemical joining or bonding of the fibers; or using heat to join or bond fibers to form the yarn. It will be understood that this step may be repeated to form multiple yarns, which are in turn joined to form a ply yarn.

[0062] At a step 500, yarn 115 and carrier 125 are formed into a base layer 120 by applying yarn 115 to a carrier 125 in a desired pattern P (FIG. 2). The base layer forming step 500 may include mechanically attaching yarn 115 to carrier 125 for example by stitching, embroidering, felting, crocheting, interlacing, interlooping, bonding, fusing, stitch forming, or interlocking the fiber(s) 110 and/or yarn 115 to carrier 125. Stitch forming may include stitching yarn 115 to carrier

125, for example with a fixing thread, as shown. Fusing or bonding may be used to attach polymer fibers or yarn by heat, light, ultrasound, adhesives, chemicals, or combinations thereof. As a further option, yarns 115 may be processed after they are formed by a mechanical, chemical, or light post process 425. Post process 425 may for example include texturing, crimping, coating, curing, heating, ultraviolet (UV) treatment and the like.

[0063] At step 600, the base layer 120 is formed into a three dimensional structure or lattice 225 including one or more raised areas or lowered areas that deviate from plane P_b of base layer 120. With base layer 120 formed into a desired lattice 225, carrier material may optionally be removed (step 650) while base layer 120 is in the mold or during a post processing step.

[0064] The step 600 may include any mechanical, chemical, thermal, or light process for forming the three dimensional structure in a processing step 610 (FIG. 7-9). These techniques may also be combined. In the example described in FIG. 6, processing step 610 includes a mechanical process such as a pressing or molding step 620 to create the raised areas 180 in base layer 120. With reference to FIGS. 7-9, a generally pyramidal shape is formed. The outer surface of base layer120 defines an external pyramid shape and the inner surface defines a similarly shaped hollow or void 220 (FIG. 4). To that end, the lattice former 630, depicted generally in FIGS. 7-9, may be a press, die, mold, or other machine that mechanically deforms sheet 125 into lattice 225 having the desired pattern P formed therein. For example, as shown in FIG. 7A, press 630 may include plural pyramidal shaped projections 635 on one side 640 and similarly shaped receivers 645 on an opposite side 650 to deform sheet 125 when the opposite sides of the press are compressed together. As discussed above, any shape may be given to raised and lowered areas and any pattern P may be formed.

[0065] After the three dimensional structure is formed, an optional treating step 660 may be used to remove carrier material or, if needed, to set the shape of pattern or otherwise improve the properties of the three dimensional lattice

225. As depicted in FIG. 6, optional step 660 may be applied if the system determines at 665 that the lattice 225 has not set or if carrier material was not removed during the formation step. If the lattice 225 is set, the step may be omitted, and consideration of further post formation finishes, coatings or treatments may be considered at step 670. For example, chemicals, heat, or light may be applied to set the shape or improve its properties, such as for example, by making it more resistive to UV light, chemically bonding the shape, hardening the shape or combinations thereof. If the lattice 225 is not set, the step of setting the lattice at 685 may include any suitable treatment including but not limited to apply heat, light, or chemicals to set the lattice. In the example process shown in FIG. 6, multiple options may be provided to account for different base layer materials such that step 660 includes a selection of setting process including but not limited to applying heat, a coating, or curing the lattice 225.

[0066] In lattices 225 where it is desired to remove carrier 125, carrier 125 may be removed at step 620 or during a post treatment step 660. In the system shown, an optional step 625 to check if the carrier 125 was removed may be implemented after step 620. If the carrier 125 was removed during formation 620, then the process proceeds to the decision as to whether the 3D structure is set as described above. If not, the process moves to a post treatment step 660, where the carrier 125 is removed by any of the processes described above including application of heat 675 to melt away carrier 125 or a solvent 680 to dissolve carrier 125, or a machining step 682 to physically remove carrier 125, for example with compressed air, bead or grit blasting, waterjet, or other cutting or machining processes. During post treatment, a setting step 685 may be applied to set the shape of lattice 225 as described above. Setting step 685 may occur before, during or after any steps to remove carrier at 660. Once post treatment 660 is complete, process may move to a decision step to determine if the lattice is properly set and return to post treatment as needed. If lattice 225 is set, process moves to the decision step 670 to determine if any post formation finishes or coatings are to be applied.

[0067] With reference to FIGS 7-9, three example cores 100 are shown for forming lattice 225. These examples are not limiting. In FIG. 7, lattice former 610 forms lattice 225 without the need for the optional step 660 and finishing step 670. In FIG. 8, the step 660 is incorporated within lattice former 610 by applying heat to the lattice as it is formed. FIG. 9 depicts another option using a post treatment tool, generally indicated by the number 690. Post treatment tool 690 may be used to remove carrier 125 after formation as discussed above or to apply heat, radiation, light, or chemicals to lattice 225 after it is formed to set the shape of lattice 225.

[0068] With the lattice 225 formed, system 100 may include the step 700 of attaching additional structures, generally indicated by the number 710, to lattice 225. For example as shown in FIGS. 10 and 11, one or more skins may be attached to a side of lattice 225. In the example shown, a first skin 715 and a second skin 720 are attached respectively to the outer extremities of lattice at surface 230 and base 245 of raised areas 180 to sandwich the raised areas 180 and voids 220 therebetween. Optionally, additional skins or other structures may be attached to lattice 225.

[0069] Skins 715,720 are generally a thin walled material, and may be formed from a first fiber-reinforced polymer material including but not limited to a laminate made from at least one of a uni-directional tape, a prepack roll, a two-dimensional fabric, a three-dimensional fabric, commingled fibers, a film, a woven fabric, and a non-woven fabric. The first fiber-reinforced polymer material may be made through a melt process, from a chemical solution, from a powder, by film impregnation, or the like. The woven and non-woven fabric materials may be made from the first thermoplastic resin. In one example, a 7-781 woven fabric woven with a PEI is used as a skin.

[0070] Continuing with the present example, system 100 with a lattice 225 sandwiched between first and second skins may be processed at 800 to form an article 810. The processing step 800 may include any machining step, molding step or combinations thereof to form a desired article. In the example shown, processing step 800 is used to form core into an article, such as a structural component 820 for a vehicle, such as in an aircraft. The depicted structural component can be used as a wall or divider in an aircraft. This example is not limiting as the system 100 may be used to form a variety of articles 810, limited only by the imagination of the designer. Several non-limiting examples of such articles 810 are provided below.

[0071] Articles, generally indicated by the number 810, produced according to the disclosure include, for example, computer and business machine housings, home appliances, trays, plates, handles, helmets, vehicle components such as aircraft structural members, walls, floors, wings, instrument panels, cup holders, glove boxes, interior coverings and the like. In various further aspects, formed articles include, but are not limited to, food service items, medical devices, animal cages, electrical connectors, enclosures for electrical equipment, electric motor parts, power distribution equipment, communication equipment, computers and the like, including devices that have molded in snap fit connectors. In a further aspect, articles of the present disclosure include exterior body panels and parts for outdoor vehicles and devices including automobiles, protected graphics such as signs, outdoor enclosures such as telecommunication and electrical connection boxes, and construction applications such as roof sections, wall panels and glazing. Multilayer articles made of the disclosed polycarbonates particularly include articles which will be exposed to UV light, whether natural or artificial, during their lifetimes, and most particularly outdoor articles; i.e., those intended for outdoor use. Suitable articles are exemplified by enclosures, housings, panels, and parts for outdoor vehicles and devices; enclosures for electrical and telecommunication devices; outdoor furniture; aircraft components; boats and marine equipment, including trim, enclosures, and housings; outboard motor housings; depth finder housings, personal water-craft; jet-skis; pools; spas; hot-tubs; steps; step coverings; building and construction applications such as glazing, roofs, windows, floors, decorative window furnishings or treatments; treated glass covers for pictures, paintings, posters, and like display items; wall panels, and doors; protected graphics; outdoor and indoor signs; enclosures, housings, panels, and parts for automatic teller machines (ATM); enclosures, housings, panels, and parts for lawn and garden tractors, lawn mowers, and tools, including lawn and garden tools; window and door trim; sports equipment and toys; enclosures, housings, panels, and parts for snowmobiles; recreational vehicle panels and components; playground equipment; articles made from plastic-wood combinations; golf course markers; utility pit covers; computer housings; desk-top computer housings; portable computer housings; lap-top computer housings; palm-held computer housings; monitor housings; printer housings; keyboards; facsimile machine housings; copier housings; telephone housings; mobile phone housings; radio sender housings; radio receiver housings; light fixtures; lighting appliances; network interface device housings; transformer housings; air conditioner housings; cladding or seating for public transportation; cladding or seating for trains, subways, or buses; meter housings; antenna housings; cladding for satellite dishes; coated helmets and personal protective equipment; coated synthetic or natural textiles; coated photographic film and photographic prints; coated painted articles; coated dyed articles; coated fluorescent articles; coated articles; and like applications.

[0072] In one aspect, the parts can include articles including the disclosed glass fiber filled polymeric materials. In a further aspect, the article including the disclosed glass fiber filled polymeric materials can be used in automotive applications. In a yet further aspect, the article includes the disclosed glass fiber filled polymeric materials can be selected from instrument panels, overhead consoles, interior trim, center consoles, panels, quarter panels, rocker panels, trim, fenders, doors, deck lids, trunk lids, hoods, bonnets, roofs, bumpers, fascia, grilles, minor housings, pillar appliqués, cladding, body side moldings, wheel covers, hubcaps, door handles, spoilers, window frames, headlamp bezels, headlamps, tail lamps, tail lamp housings, tail lamp bezels, license plate enclosures, roof racks, and running boards. In an even further aspect, the article including the disclosed glass fiber filled polymeric materials can be selected from mobile device exteriors, mobile device covers, enclosures for electrical and electronic assemblies, protective headgear, buffer edging for furniture and joinery panels, luggage and protective carrying cases, small kitchen appliances, and toys.

[0073] In one aspect, the parts can include electrical or electronic devices including the disclosed glass fiber filled polymeric materials. In a further aspect, the electrical or electronic device can be a cellphone, a MP3 player, a computer, a laptop, a camera, a video recorder, an electronic tablet, a pager, a hand receiver, a video game, a calculator, a wireless car entry device, an automotive part, a filter housing, a luggage cart, an office chair, a kitchen appliance, an electrical housing, an electrical connector, a lighting fixture, a light emitting diode, an electrical part, or a telecommunications part.

[0074] Aspects of the disclosure may utilize an injection molding barrel/screw (not shown). An injection molding barrel/screw may include a hopper. Pellets of thermoplastic material and/or fiber reinforced thermoplastics may be supplied by the hopper to the injection molding barrel/screw. In some aspects, a gas (blowing agent) from a gas source may be introduced. The injection molding barrel/screw may include a cylinder maintaining a screw. The screw may further include a motor or the like for moving the screw. Additionally, the injection molding barrel/screw may include at least one heater. A nozzle and/or an associated shutoff valve may include at least one heater to maintain a temperature of the pellets and/or increase the temperature of the pellets to melt the same. Other constructions associated with the injection molding barrel/screw are contemplated as well.

[0075] Examples

[0076] Example 1. A core formed by a process comprising: forming a yarn having a first fiber and a second fiber, wherein the first fiber is a polymer fiber and the second fiber is a reinforcing fiber; providing the yarn in a pattern defining a base plane, and deforming the yarn at least normal to the base plane to form a three dimensional lattice incorporating the pattern.

[0077] Example 2. The core of example 1, wherein the first fiber and second fiber have different properties relative to each other.

[0078] Example 3. The core of one of examples1 or 2, wherein the first fiber is a polymer fiber and the second fiber is a reinforcing fiber.

[0079] Example 4. The core of example 3, wherein the polymer fiber is selected from the group consisting of polycarbonates, polyetherimides (PEI), polyetheretherketones (PEEK), polyetherketoneketone (PEKK), polyetherketone (PEK), polypropylenes, polyethylenes, including polytetrafluoroethylene (PTFE), polystyrenes, polyvinyls, including polyvinyl chlorides (PVC), polyethylene terephthalates, polybutylene terephthalates (PBT), polyoxymethylene (POM), poly(p-phenylene ether) (PPE), acetals, acrylics, nylons, thermoplastic polyurethanes, polyacetals, polyphenylene sulfides, cycloolefins, thermotropic polyesters, acrylonitrile butadiene styrene (ABS), an ionomer thereof, a copolymer thereof, or a combination comprising at least one of the foregoing.

[0080] Example 5. The core of example 4, wherein the reinforcing fiber is selected from the group consisting of a carbon fiber, a glass fiber, an aramid fiber, a basalt fiber, a quartz fiber, a boron fiber, a cellulose fiber, a natural fiber, a liquid crystal polymer fiber, a high tenacity polymer fiber, a polypropylene, polyethylene, poly(hexano-6-lactam),poly-imino(1,6-dioxohexamethylene) imnohexamethylene), or a combination of at least one of the foregoing.

[0081] Example 6. The core of examples 1-5, wherein the yarn has a thickness in a range from about .5 mm to about 3 mm; wherein the first fiber has a thickness in a range from about 5 micrometers to about 20 micrometers; and wherein the second fiber has a thickness in a range from about 5 micrometers to about 20 micrometers.

[0082] Example 7. The core of example 1 wherein the carrier material between yarns within the pattern is removed before the lattice is formed.

[0083] Example 8. The core of one of examples 1 to 7, wherein the lattice includes an outer extremity and a base, wherein the outer extremity and the base are generally parallel to each other.

[0084] Example 9. The core of examples 1 to 8, where the pattern is substantially x-shaped to form a pyramid shaped lattice.

[0085] Example 10. The core of one of examples 1 to 9 further comprising a first skin attached to one side of the lattice and a second skin attached to another side of the lattice.

[0086] Example 11. A system for forming a core comprising the steps of forming a yarn from polymer fiber and a reinforcing fiber, forming a two dimensional base layer with the yarn applied to a carrier forming a base plane, and deforming the base layer at least perpendicular to the base plane at repeated intervals to form a three dimensional lattice.

[0087] Example 12. The system of example 11, wherein the step of forming the two dimensional base layer includes at least one of stitching, embroidering, adhering, and welding the yarn to the carrier.

[0088] Example 13. The system of example 11, wherein the step of deforming the base layer includes pressing the two dimensional base layer with a press.

[0089] Example 14. The system of example 11, wherein the step of deforming the base layer includes forming at least one raised area having an outer surface that extends substantially parallel to the base plane.

[0090] Example 15. The system of examples 11-14 further comprising attaching a first skin to one side of the lattice and attaching a second skin to another side of the lattice.

[0091] Example 16. The system of example 11, wherein the step of deforming the base layer includes forming plural raised areas extending outward from the base layer.

[0092] Example 17. The system of example 11, wherein the yarn applied to the carrier forms a pattern.

[0093] Example 18. The system of example 17, wherein the pattern is substantially x-shaped to form a substantially tetrahedron shaped raised area in the three dimensional lattice.

[0094] Example 19. The system of examples 11-18 further comprising the step of applying at least one of a heat, a light, a radiation, or a chemical to the lattice.

[0095] Example 20. The system of one of examples11-19 further comprising the step of processing at least the lattice to form an article.

[0096] Example 21. A core comprising: at least one yarn arranged in a pattern on a carrier and deformed to form the pattern into a three dimensional lattice, the carrier being removable after the lattice is formed, the lattice defining a base plane and having at least one raised area extending at least normal to the base plane, wherein the yarn includes a first fiber and a second fiber, wherein the first fiber and second fiber have different material properties.

[0097] Example 22. The core of example 21, wherein the first fiber is a polymer fiber and the second fiber is a reinforcing fiber.

[0098] Example 23. The core of examples 21, wherein the yarn has a thickness in a range from about .5 mm to about 3 mm; wherein the first fiber has a thickness in a range from about 5 micrometers to about 20 micrometers; and wherein the second fiber has a thickness in a range from about 5 micrometers to about 20 micrometers.

[0099] Example 24. The core of one of examples 21-23 further comprising a first skin attached to the lattice.

[00100] Example 25. The core of example 24 further comprising a second skin attached to the lattice.

[00101] Example 26. The core of example 25, wherein the first skin, three dimensional lattice and second form an article.

[00102] Example 27. The core of any of the foregoing examples, where the yarn is attached to a carrier by at least one of a stitch, a weld, and an embroidery.

[00103] While the disclosure has been described in terms of exemplary aspects, those skilled in the art will recognize that the disclosure can be practiced with modifications in the spirit and scope of the appended claims. These examples given above are merely illustrative and are not meant to be an exhaustive list of all possible designs, aspects, applications or modifications of the disclosure.

WHAT IS CLAIMED IS:

1. A core formed by a process comprising: forming a yarn having a first fiber and a second fiber, wherein the first fiber is a polymer fiber and the second fiber is a reinforcing fiber; providing the yarn in a pattern defining a base plane, and deforming the yarn at least normal to the base plane to form a three dimensional lattice incorporating the pattern.

2. The core of claim 1, wherein the polymer fiber is selected from the group consisting of polycarbonates, polyetherimides (PEI), polyetheretherketones (PEEK), polyetherketoneketone (PEKK), polyetherketone (PEK), polypropylenes, polyethylenes, including polytetrafluoroethylene (PTFE), polystyrenes, polyvinyls, including polyvinyl chlorides (PVC), polyethylene terephthalates, polybutylene terephthalates (PBT), polyoxymethylene (POM), poly(p-phenylene ether) (PPE), acetals, acrylics, nylons, thermoplastic polyurethanes, polyacetals, polyphenylene sulfides, cycloolefins, thermotropic polyesters, acrylonitrile butadiene styrene (ABS), an ionomer thereof, a copolymer thereof, or a combination comprising at least one of the foregoing.

3. The core of claim 1, wherein the reinforcing fiber is selected from the group consisting of a carbon fiber, a glass fiber, an aramid fiber, a basalt fiber, a quartz fiber, a boron fiber, a cellulose fiber, a natural fiber, a liquid crystal polymer fiber, a high tenacity polymer fiber, a polypropylene, polyethylene, poly(hexano-6-lactam), poly-imino(1,6-dioxohexamethylene) imnohexamethylene), or a combination of at least one of the foregoing.

4. The core of claim 1, wherein the first fiber is a polyetherimide fiber and the reinforcing fiber is at least one of a carbon, glass, and aramid fiber.

5. The core of claim 1, wherein the yarn has a thickness in a range from about .5 mm to about 3 mm; wherein the first fiber has a thickness in a range from about 5 micrometers to about 20 micrometers; and wherein the second fiber has a thickness in a range from about 5 micrometers to about 20 micrometers.

6. The core of claim 1, wherein the step of providing the yarn includes applying the yarn on a carrier, and wherein during the step of deforming or after the step of deforming, the carrier is removed.

7. The core of claim 6, wherein the step of applying the yarn on the carrier includes at least one of stitching, embroidering, adhering, and welding the yarn to the carrier.

8. The core of one of claims 1 to 7, wherein the step of deforming includes forming the lattice to include an outer extremity and a base, where the base lies in the base plane and the outer extremity is spaced outwardly therefrom, and wherein the outer extremity and the base are generally parallel to each other.

9. The core of one of claims 1 to 7, where the pattern is substantially x-shaped, and deformed to form a pyramid shaped lattice.

10. The core of one of claims 1 to 8 further comprising the step of attaching a first skin to one side of the lattice and a second skin to another side of the lattice.

11. The core of claim 10 further comprising the step of processing at least the lattice to form an article.

12. The core of claim 1, wherein the step of deforming includes pressing the pattern with a press.

13. The core of claim 1 further comprising the step of applying at least one of a heat, a light, a radiation, or a chemical to the lattice.

14. A core comprising: at least one yarn, wherein the at least one yarn includes a first fiber and a second fiber, wherein the first fiber is a polymer fiber and the second fiber is a reinforcing fiber; the at least one yarn being arranged in a pattern, the pattern being deformable to define a three dimensional lattice, the lattice defining a base plane and having at least one raised area extending at least normal to the base plane.

15. The core of claim 14, wherein the polymer fiber is selected from the group consisting of polycarbonates, polyetherimides (PEI), polyetheretherketones (PEEK), polyetherketoneketone (PEKK), polyetherketone (PEK), polypropylenes, polyethylenes, including polytetrafluoroethylene (PTFE), polystyrenes, polyvinyls, including polyvinyl chlorides (PVC), polyethylene terephthalates, polybutylene terephthalates (PBT), polyoxymethylene (POM), poly(p-phenylene ether) (PPE), acetals, acrylics, nylons, thermoplastic polyurethanes, polyacetals, polyphenylene sulfides, cycloolefins, thermotropic polyesters, acrylonitrile butadiene styrene (ABS), an ionomer thereof, a copolymer thereof, or a combination comprising at least one of the foregoing.

16. The core of claim 14, wherein the reinforcing fiber is selected from the group consisting of a carbon fiber, a glass fiber, an aramid fiber, a basalt fiber, a quartz fiber, a boron fiber, a cellulose fiber, a natural fiber, a liquid crystal polymer fiber, a high tenacity polymer fiber, a polypropylene, polyethylene, poly(hexano-6-lactam), poly-imino(1,6-dioxohexamethylene) imnohexamethylene), or a combination of at least one of the foregoing.

17. The core of claim 14, wherein the polymer fiber is a polyetherimide and the reinforcing fiber is at least one of a carbon, glass, and aramid fiber.

18. The core of claim 14, wherein the at least one yarn has a thickness in a range from about .5 mm to about 3 mm; wherein the first fiber has a thickness in a range from about 5 micrometers to about 20 micrometers; and wherein the second fiber has a thickness in a range from about 5 micrometers to about 20 micrometers.

19. The core of claim 14 further comprising a carrier, wherein the yarn is embroidered on to the carrier to form the pattern; and wherein the carrier is removable from the lattice.

20. The core of one of claims 14 to 18 further comprising a first skin attached to one side of the lattice and a second skin attached to another side of the lattice.

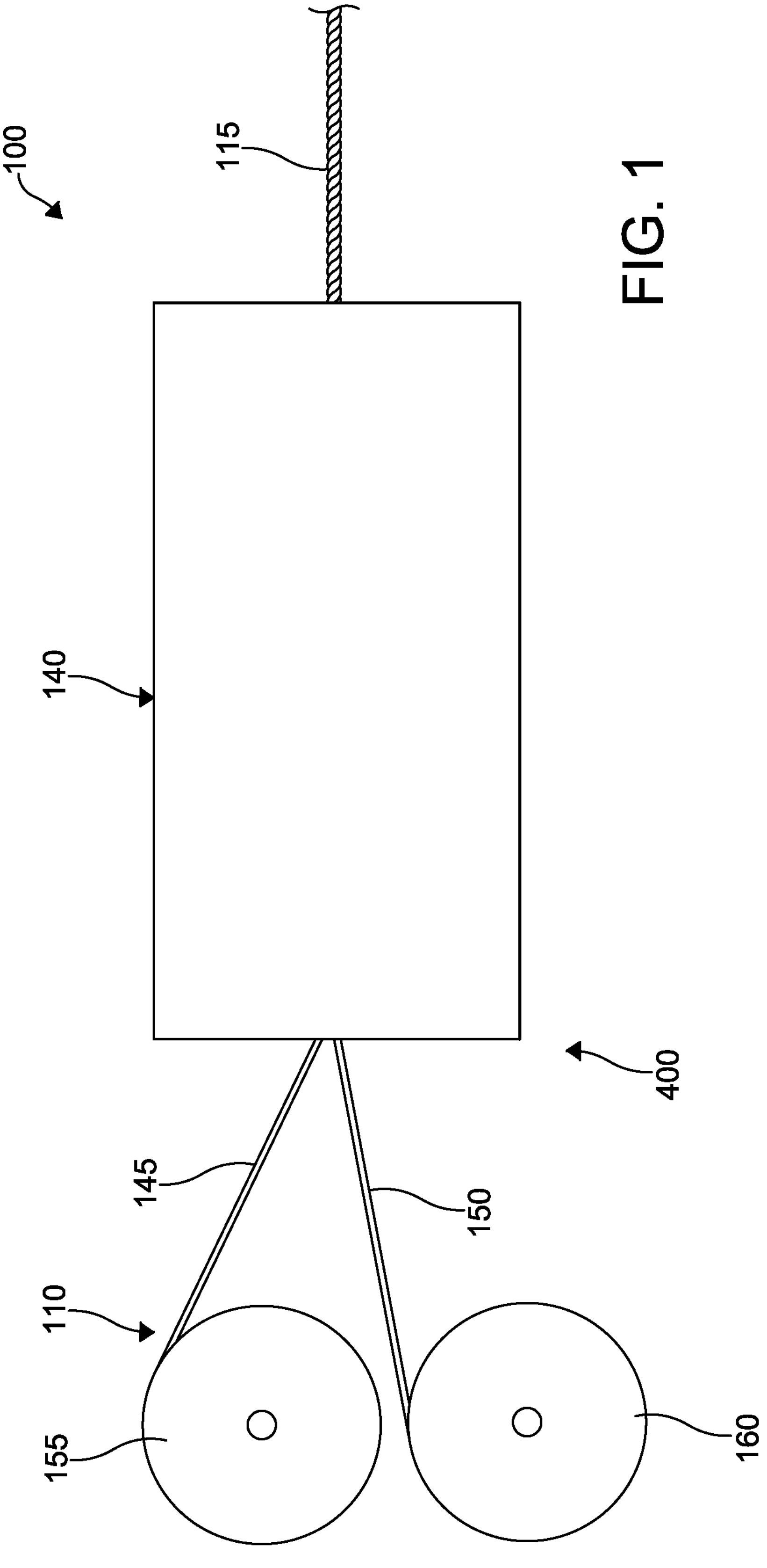


FIG. 1

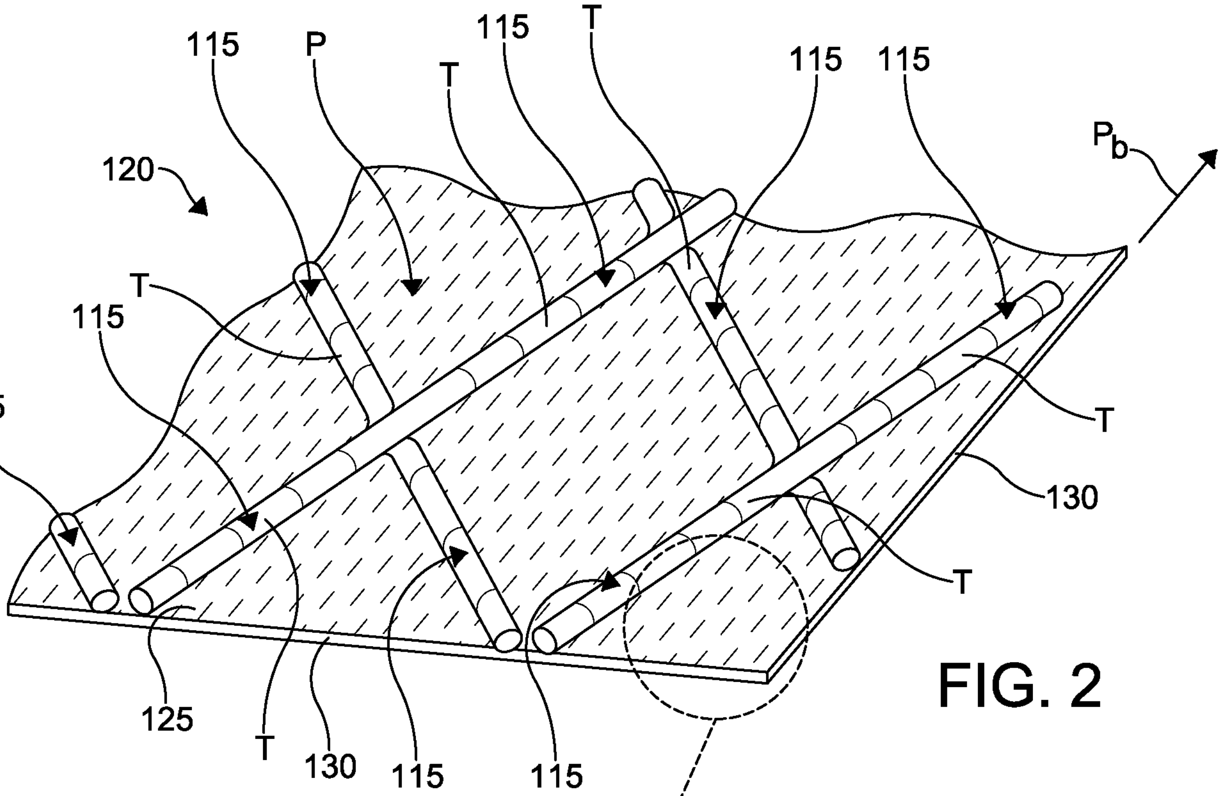
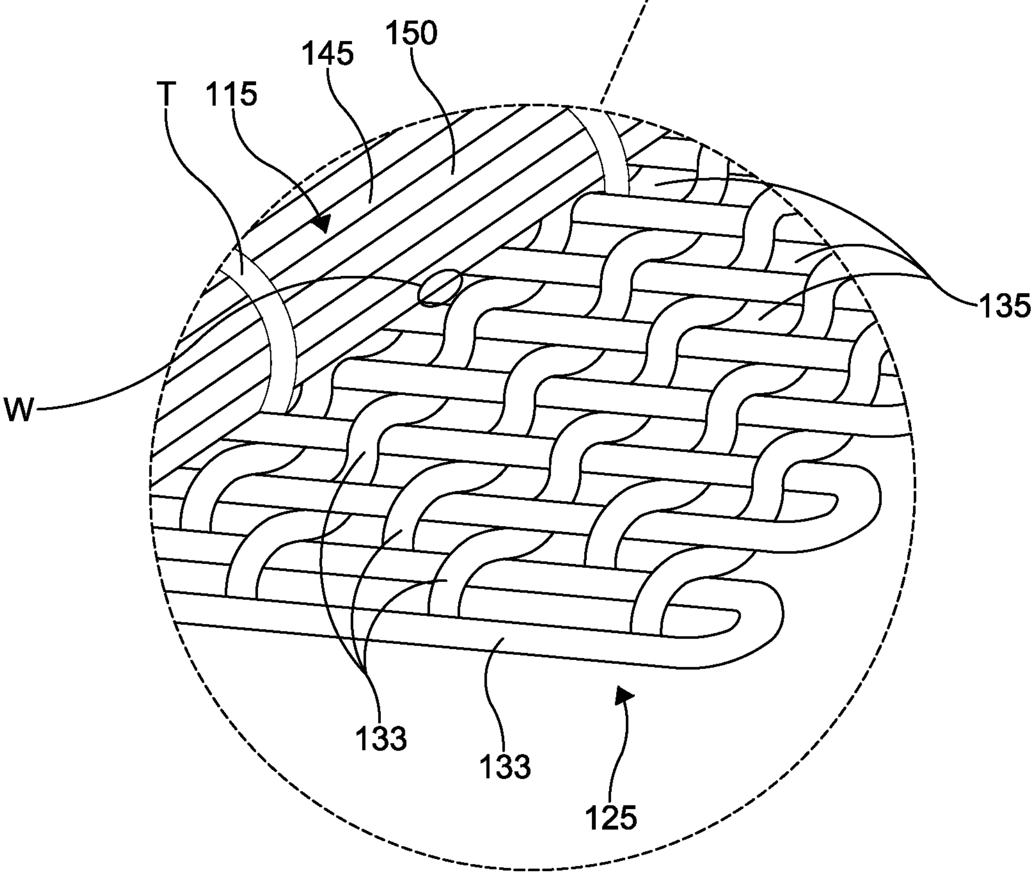

115
P
115
T
T
115
115
120
Pb
T
115
115
T
130
T
125
T
130
115
115

FIG. 2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150
T
115
135
W
133
133
125

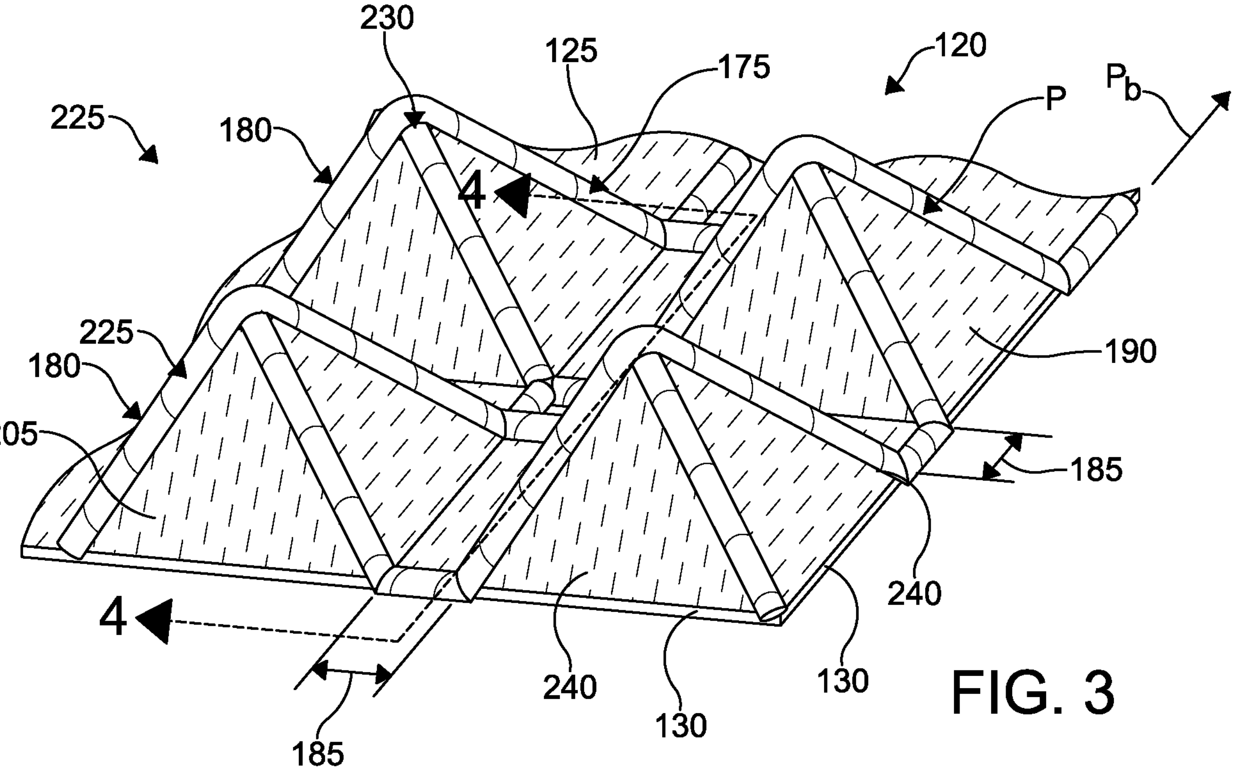
230
125
175
120
225
180
4
P
Pb
225
180
205
190
185
240
4
185
240
130
130

FIG. 3

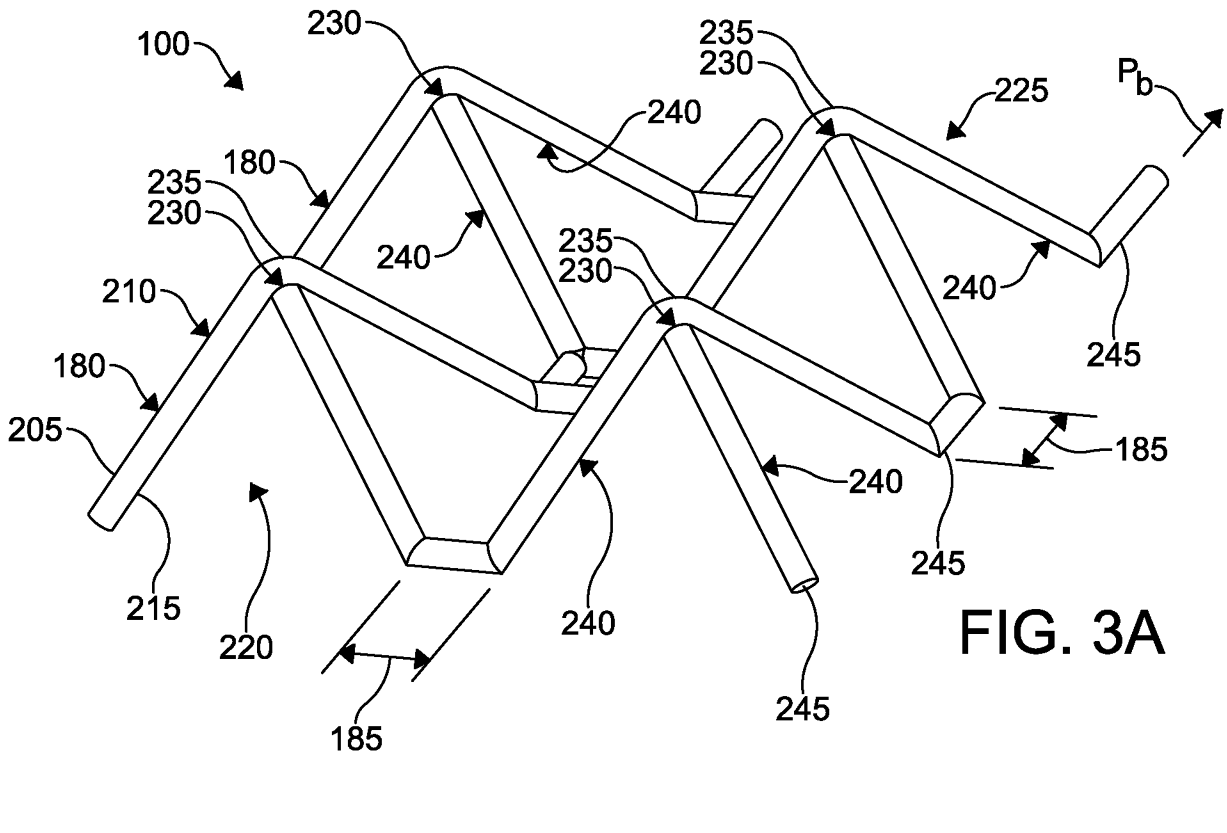
230
100
235
230
225
Pb
240
180
235
230
240
210
235
230
240
245
180
205
185
240
245
215
220
240
245
185

FIG. 3A

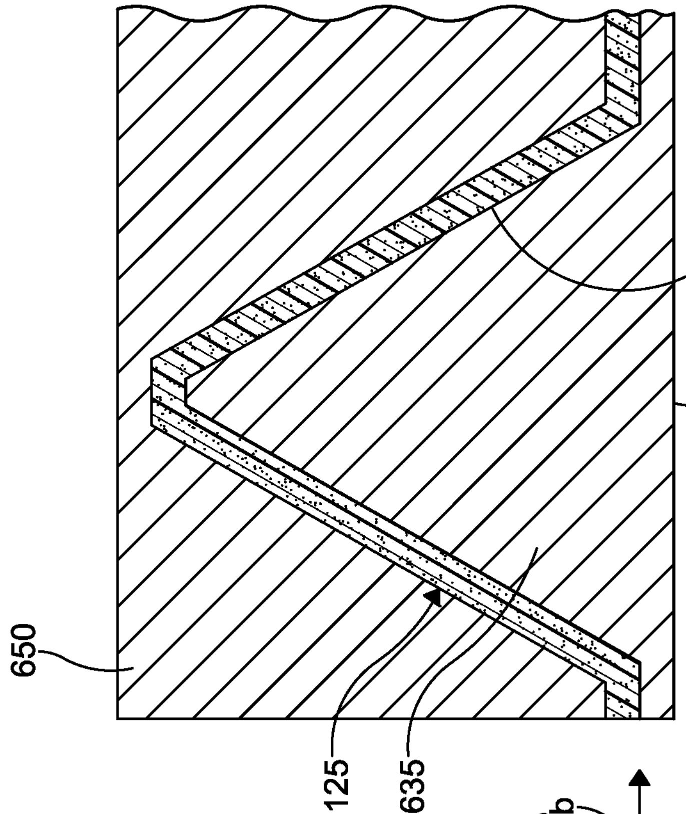
650
125
635
640
645

FIG. 4B

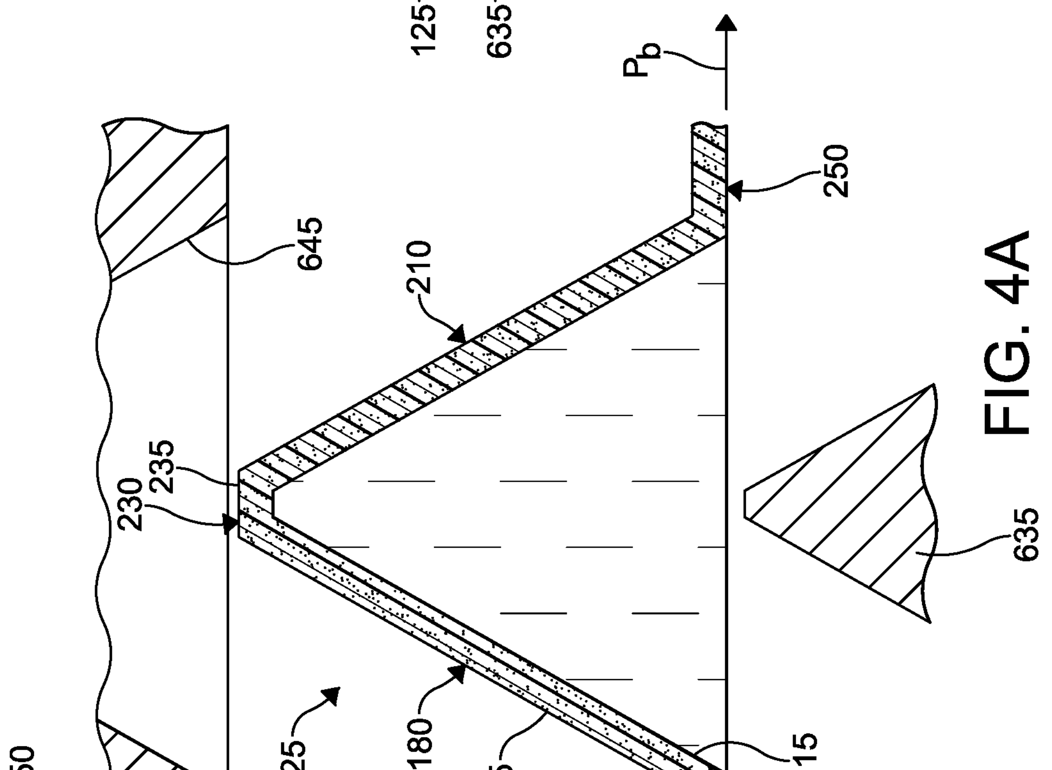
Pb
650
125
180
205
215
245
230
235
210
645
250
635

FIG. 4A

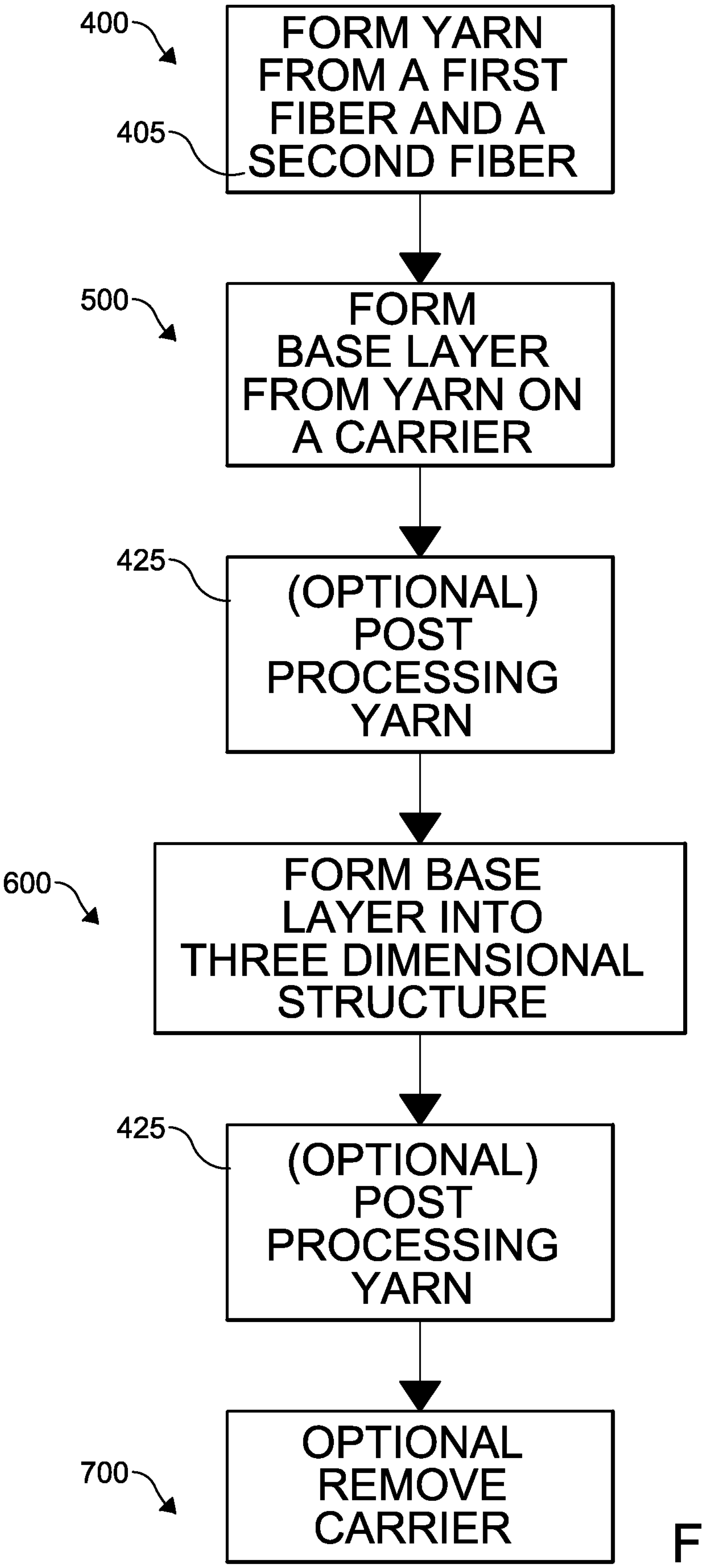
400
FORM YARN FROM A FIRST FIBER AND A SECOND FIBER
405
500
FORM BASE LAYER FROM YARN ON A CARRIER
425
(OPTIONAL) POST PROCESSING YARN
600
FORM BASE LAYER INTO THREE DIMENSIONAL STRUCTURE
425
(OPTIONAL) POST PROCESSING YARN
700
OPTIONAL REMOVE CARRIER

FIG. 5

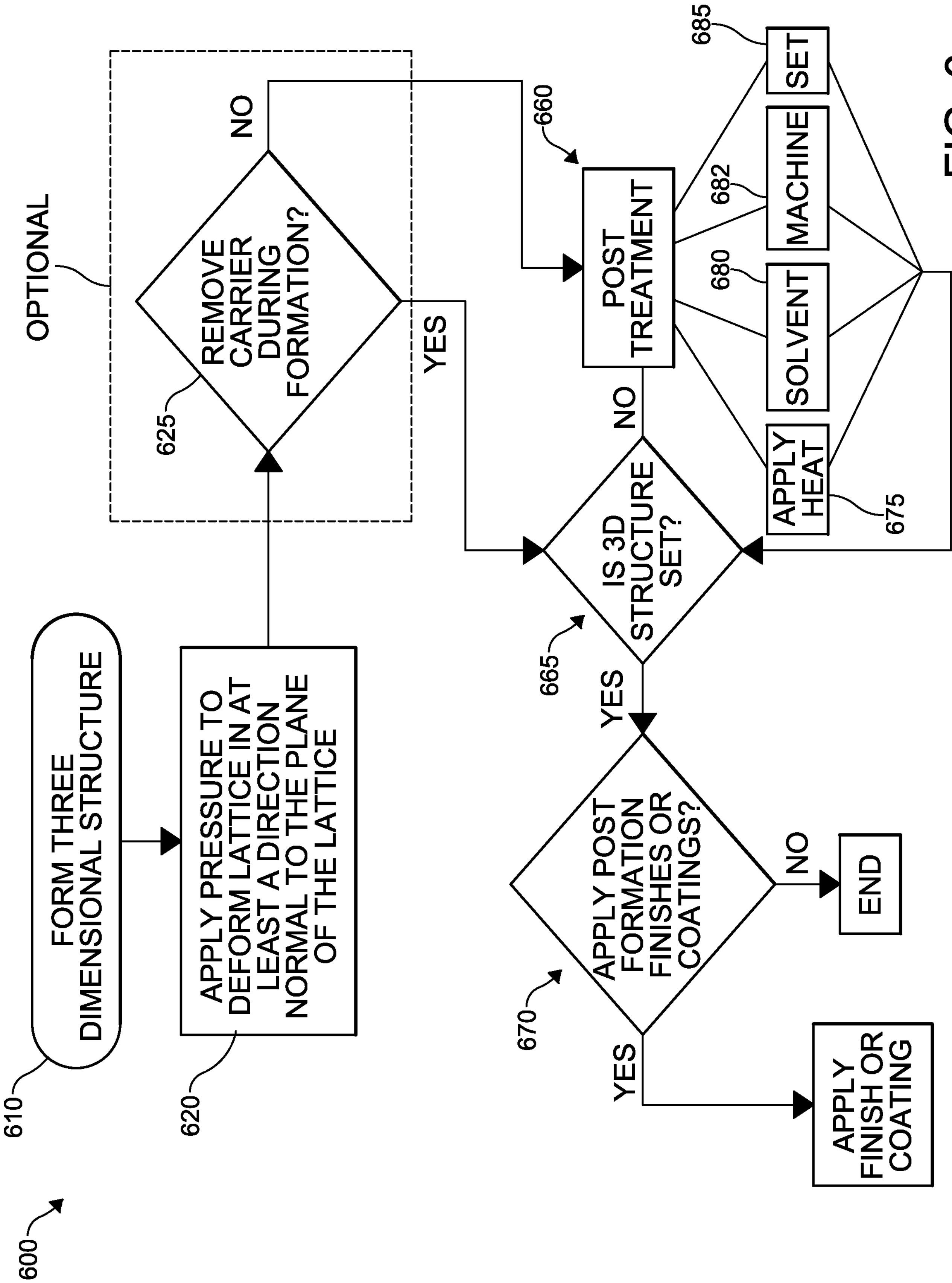
600
610
FORM THREE DIMENSIONAL STRUCTURE
620
APPLY PRESSURE TO DEFORM LATTICE IN AT LEAST A DIRECTION NORMAL TO THE PLANE OF THE LATTICE
OPTIONAL
625
REMOVE CARRIER DURING FORMATION?
NO
YES
660
POST TREATMENT
675
APPLY HEAT
680
SOLVENT
682
MACHINE
685
SET
665
IS 3D STRUCTURE SET?
NO
YES
670
APPLY POST FORMATION FINISHES OR COATINGS?
NO
END
YES
APPLY FINISH OR COATING

FIG. 6

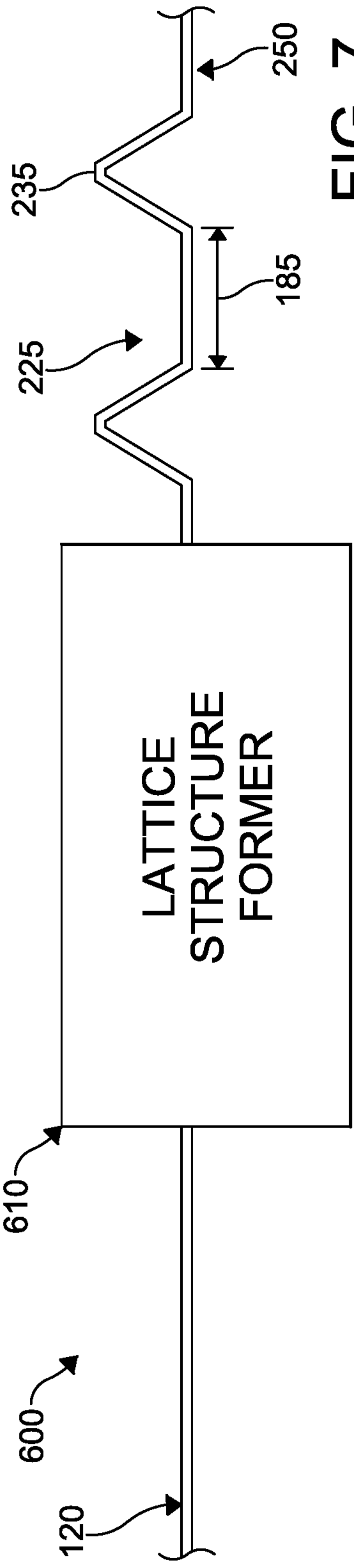

FIG. 7

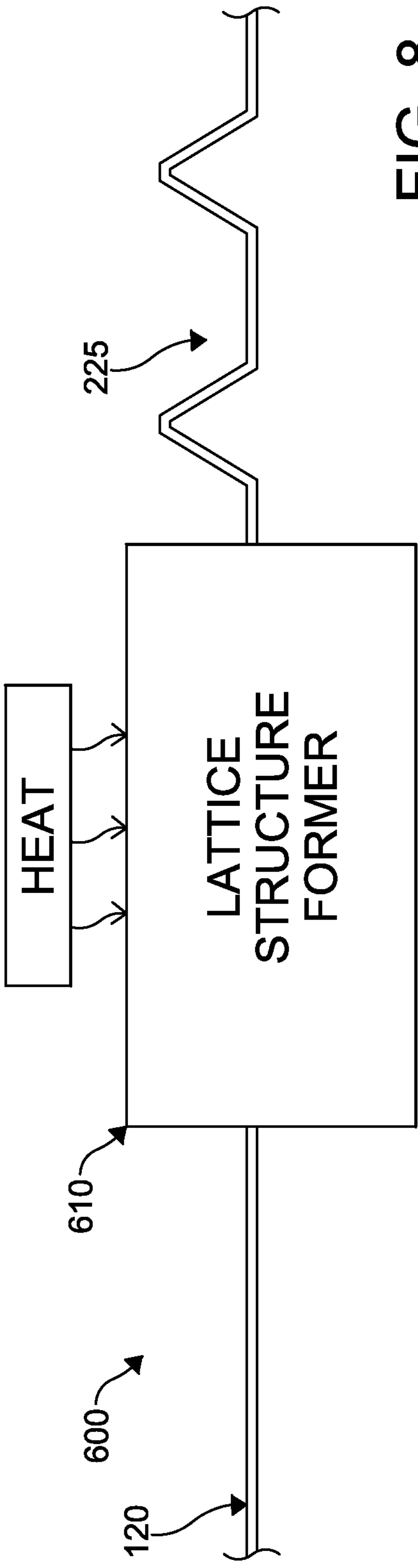

FIG. 8

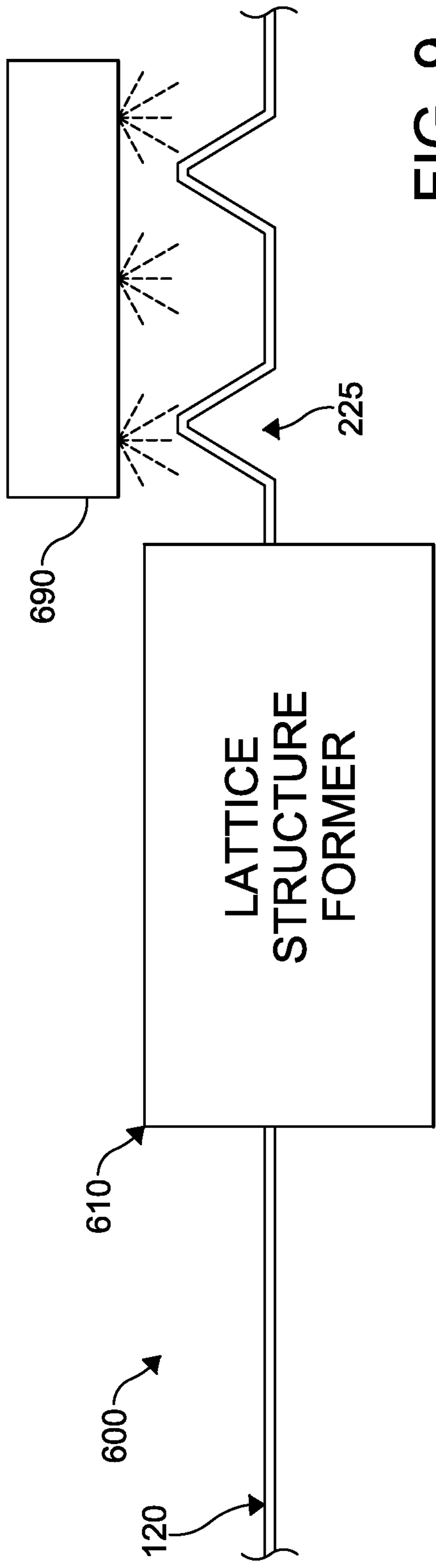

FIG. 9

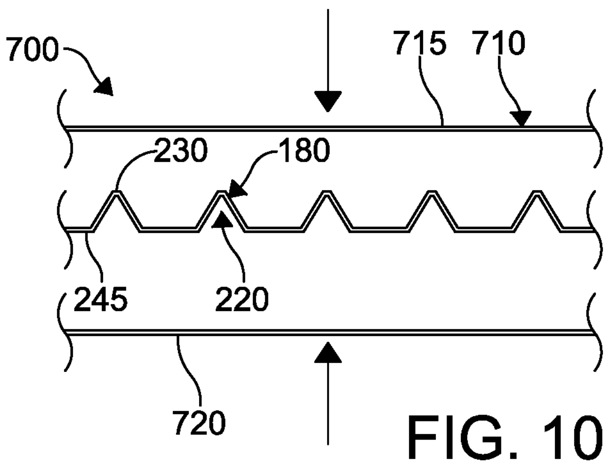

FIG. 10

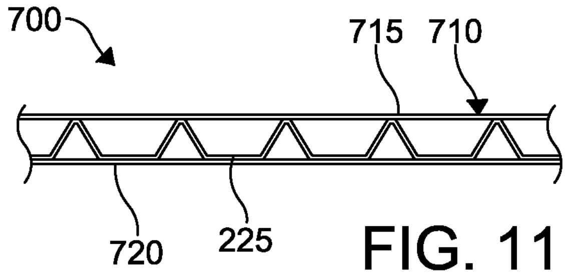

FIG. 11

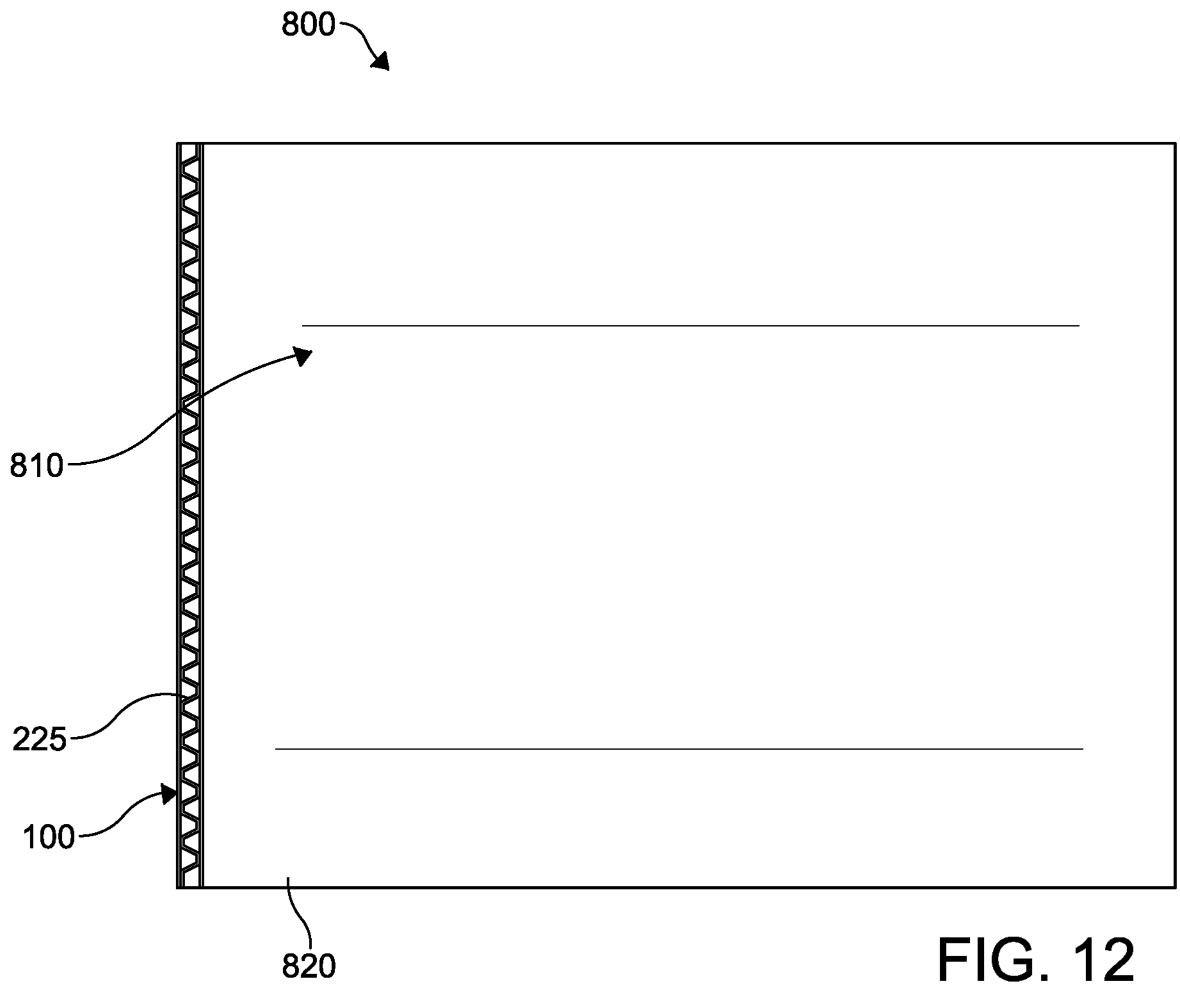

FIG. 12

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2018/038707

A. CLASSIFICATION OF SUBJECT MATTER
INV. D04H3/002 D04H3/009 D04H3/07 B29C51/00
ADD.

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)
D04H B29C

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)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US 5 364 686 A (DISSELBECK DIETER [DE] ET AL) 15 November 1994 (1994-11-15) column 1, line 11; claims 3,4; figures 1,2; example 1	1-4,6-8, 10-17,20 5,9,18, 19
A	EP 0 469 558 A1 (HOECHST AG [DE]) 5 February 1992 (1992-02-05) claims; figures	1-20
A	EP 0 324 714 A2 (TEXTEC TEXTIL ENG & CONSULT [DE]) 19 July 1989 (1989-07-19) abstract; claims	1-14
A	US 2017/028601 A1 (SONI RANVIR KUMAR [US] ET AL) 2 February 2017 (2017-02-02) abstract; claims; figures	1-20

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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"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
28 August 2018	05/09/2018

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Elsässer, Ralf

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2018/038707

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