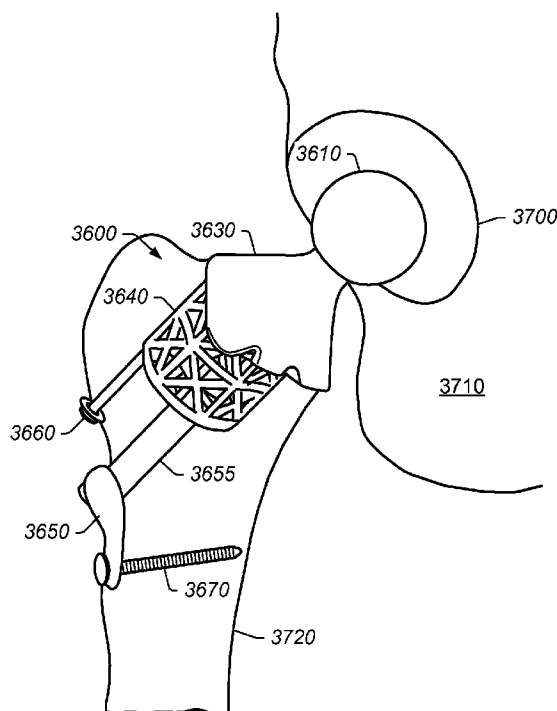




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(54) Title: PROSTHETIC IMPLANT FOR BALL AND SOCKET JOINTS AND METHOD OF USE



(57) Abrégé/Abstract:

A hip prosthesis includes an acetabular cup and a femoral component comprising a head and a stem, wherein the stem comprises a truss structure, the truss structure comprising a space truss comprising a plurality of planar truss units having a plurality of struts joined at nodes, wherein the web structure is configured to interface with bone tissue.



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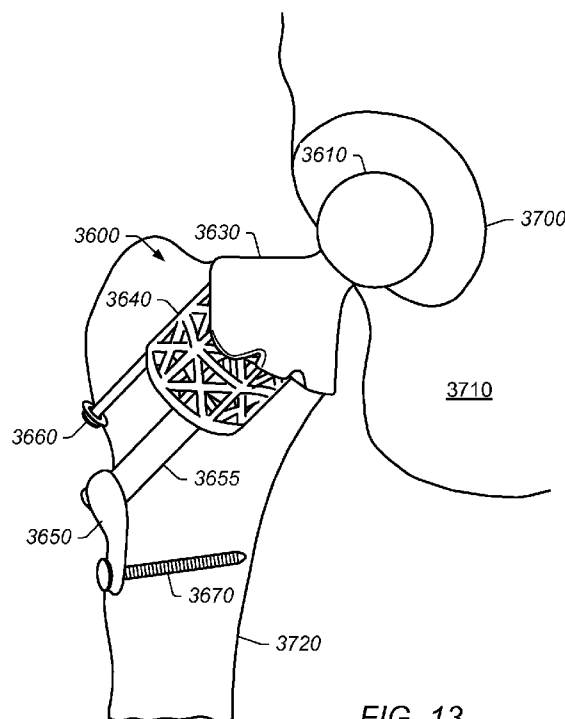


FIG. 13

(57) Abstract: A hip prosthesis includes an acetabular cup and a femoral component comprising a head and a stem, wherein the stem comprises a truss structure, the truss structure comprising a space truss comprising a plurality of planar truss units having a plurality of struts joined at nodes, wherein the web structure is configured to interface with bone tissue.

TITLE: PROSTHETIC IMPLANT FOR BALL AND SOCKET JOINTS AND METHOD OF USE

BACKGROUND

1. Field of the Invention

[0001] The present invention relates generally to medical devices and, more specifically, to implants.

2. Description of the Related Art

[0002] Implants may be used in human and/or animals to support and/or secure one or more bones. For example, implants may be used in the spine to support and/or replace damaged tissue between the vertebrae in the spine. Once implanted between two vertebrae, the implant may provide support between the two vertebrae and bone growth may take place around and through the implant to at least partially fuse the two vertebrae for long-term support. Implants may include relatively large rims with solid material that may cover, for example, 50% of the area that interacts with the endplate. The rim may provide a contact area between the implant and the vertebral endplates. Large rims may have several drawbacks. For example, large rims may impede bone growth and reduce the size of the bone column fusing the superior and inferior vertebral bodies.

[0003] Spinal implants may include open channels through the center of the supporting rims in a superior/inferior direction. The open channel design may require members of the implant that separate the rims that interact with the vertebral endplates to absorb the compressive forces between the vertebral endplates. This may increase the pressure on smaller areas of the vertebral endplates and may potentially lead to stress risers in the vertebral endplates. Further, while bone graft material is often used in conjunction with implants to encourage bone growth, the open column design of implants may reduce the likelihood of bone graft material from securing itself to the implant which could result in a bio-mechanical cooperation that is not conducive to promoting good fusion.

[0004] Bone graft material may be packed into the implant in a high-pressure state to prevent bone graft material from exiting the implant while being placed between the vertebral endplates. The high-pressure state may also reduce the potential for the bone graft material loosening due to motion between the implant and the vertebral endplates or compressive forces experienced during settling of the implant. In addition, a high-pressure environment may allow the bone graft material to re-model and fuse at greater strength. High-pressure states, however, may be difficult to create and maintain for the bone graft material in an implant.

SUMMARY

[0005] Various embodiments of implant systems and related apparatus, and methods of operating the same are described herein. In various embodiments, provided is an implant for interfacing with a bone structure includes a web structure, including a space truss, configured to interface with human bone tissue. The space truss includes two or more planar truss units having a plurality of struts joined at nodes.

[0006] In certain embodiments, an implant includes a web structure configured to interface with human bone tissue. The implant includes a space truss and an external truss. The space truss includes two or more planar truss units having a plurality of struts joined at nodes. The external truss includes one or more planar trusses having two or more adjacent planar truss units that lie in substantially the same plane.

[0007] In some embodiments, the planar truss units include a planar triangular truss unit having three substantially straight struts and three nodes in a triangular configuration. The space truss may include a plurality of planar truss units coupled to one another, wherein each of the truss units lies in a plane that is not substantially parallel to a plane of an adjacent truss unit that shares at least one strut.

[0008] In some embodiments, at least one strut passes through the central portion of the implant. At least one strut may connect two or more opposing vertices of the square shaped common truss unit. At least one strut may connect two opposed vertices of the octahedron.

[0009] In some embodiments, the implant includes an external truss structure. The external truss structure includes one or more planar trusses comprising two or more planar truss units disposed proximate an exterior of the space truss. The external truss structure includes at least one of a top, a bottom, or a side portion of the web structure.

[0010] The implant may include top and bottom faces wherein at least a portion of the top and bottom faces are angled relative to one another to provide lordosis. The lordosis may be configured to be greater than approximately four degrees. The implant further includes a top external truss structure portion and a bottom external truss structure portion angled relative to one another such that a thickness of an anterior or a posterior region of the implant is greater than a thickness of the other of the anterior or the posterior region of the implant.

[0011] The web structure is configured to provide support along at least four planes of the implant to bear against tensile, compressive, and shear forces acting on the implant.

[0012] In some embodiments, the space truss comprises truss units forming a plurality of tetrahedrons. At least two of the plurality of tetrahedrons are coupled together via one or more struts connecting two respective vertices on each of the two tetrahedrons. The space truss may

include a plurality of tetrahedrons, and wherein at least two of the tetrahedrons share a common truss unit to form a hexahedron. The space truss may include at least five truss units forming a pyramid. At least two of the pyramids are arranged opposing one another such that they share a square shaped common truss unit at their base to form an octahedron.

[0013] The implant may be configured for use as a spinal implant, a corpectomy device, in a hip replacement, in a knee replacement, in a long bone reconstruction scaffold, foot and ankle implant, shoulder implant, a joint replacement or in a cranio-maxifacial implant.

[0014] In some embodiments, the plurality of struts of the web structure have a diameter less than approximately five millimeters. In some embodiments, the struts that create the space truss comprises a biologic, growth factor or antimicrobial coupled thereto.

[0015] The implant may include an implant body comprising one or more contact faces configured to be disposed at or near a bony structure during use, wherein the web structure is disposed on the contact surface, and wherein the web structure includes two or more struts extending from the contact surface, and wherein two or more of the struts define an opening configured to enable bone through growth through the opening.

[0016] In some embodiments, a method is provided that includes accessing an intersomatic space and inserting an implant into the intersomatic space. The implant includes a web structure that includes a space truss to interface with human bone tissue. The space truss includes two or more planar truss units having a plurality of struts joined at nodes.

[0017] In certain embodiments, a method of making an implant includes storing a three-dimensional model of the implant on a storage medium, applying a layer of material to a support, moving an electron beam relative to the support to melt a portion of the material, wherein the electron beam is moved in a pattern determined from the three-dimensional model of at least a portion of the implant, and removing the implant from the support. The implant includes a web structure that includes a space truss to interface with human bone tissue. The space truss includes two or more planar truss units having a plurality of struts joined at nodes.

[0018] In some embodiments, provided is an implant that includes an implant body having one or more contact faces to be disposed at or near a bony structure, and a truss structure coupled to the contact face. The truss structure is to be disposed adjacent the bony structure during use, and includes two or more struts extending from the contact surface, wherein two or more of the struts define an opening to enable bone through growth through the opening.

[0019] In certain embodiments, provided is a method that includes slitting at least a portion of a bony structure to form one or more slits extending from a face of the bony structure into the bony structure, and inserting at least a portion of a truss structure of an implant into at least one of the

slits. The implant includes an implant body having one or more contact faces to be disposed at or near the bony structure and the truss structure coupled to the contact face. The truss structure is to be disposed adjacent the bony structure during use, and the truss structure includes two or more struts extending from the contact surface, wherein two or more of the struts define an opening to enable bone through growth through the opening.

[0020] In some embodiments, provided is a foot and/or ankle implant, including a web structure having a space truss with two or more planar truss units having a plurality of struts joined at nodes. The web structure is configured to be disposed in a foot and/or ankle.

[0021] In certain embodiments, provided is method that includes providing an opening in a foot and/or ankle of a human and installing, into the opening a web structure including a space truss having two or more planar truss units having a plurality of struts joined at nodes.

[0022] In certain embodiments, provided is a method that includes installing, between two separated bone portions, a web structure comprising a space truss comprising two or more planar truss units having a plurality of struts joined at nodes.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] A better understanding of the present invention may be obtained when the following detailed description is considered in conjunction with the following drawings, in which:

[0024] FIGS. 1A-1B illustrate views of an implant with lordosis, according to an embodiment;

[0025] FIGS. 2A-2D illustrate views of an implant without lordosis, according to an embodiment;

[0026] FIGS. 3A-3B illustrate a web structure formed with triangular-shaped building blocks, according to an embodiment;

[0027] FIGS. 4A-4B illustrate a top structure of an internal web structure of the implant, according to an embodiment;

[0028] FIGS. 5A-5C illustrate progressive sectioned views of the implant showing the internal structure of the implant, according to an embodiment;

[0029] FIG. 5D illustrates an isometric view of the implant, according to an embodiment;

[0030] FIGS. 6A-6D illustrate another configuration of the web structure, according to an embodiment;

[0031] FIG. 7A illustrates a web structure formed with two pyramids, according to an embodiment;

[0032] FIG. 7B illustrates a web structure formed with two heptahedrons, according to an embodiment;

[0033] FIG. 7C illustrates a web structure formed with two dodecahedrons, according to an embodiment;

[0034] FIGS. 8A-8D illustrate different web structure building blocks, according to various embodiments;

[0035] FIG. 9 illustrates a random web structure, according to an embodiment;

[0036] FIG. 10 illustrates a flowchart of a method for making an implant, according to an embodiment;

[0037] FIG. 11 illustrates a flowchart of a method for implanting a spinal implant, according to an embodiment;

[0038] FIG. 12 depicts an embodiment of a femoral component of a hip prosthesis;

[0039] FIG. 13 depicts an embodiment of a hip prosthesis implanted in a subject; and

[0040] FIG. 14 depicts an alternate embodiment of a hip prosthesis implanter in a subject.

[0041] While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof are shown by way of example in the drawings and will herein be described in detail. It should be understood, however, that the drawings and detailed description thereto are not intended to limit the invention to the particular form disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the present invention as defined by the appended claims. Note, the headings are for organizational purposes only and are not meant to be used to limit or interpret the description or claims.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0042] FIGS. 1A-1B illustrate views of implant 100, according to an embodiment. Implant 100 may be used, for example, in anterior lumbar inter-body fusion (ALIF) or posterior lumbar inter-body fusion (PLIF). In some embodiments, implant 100 may include a web structure 101 with one or more trusses 102 (e.g., planar and space trusses). Implant 100 and its web structure 101 may be used in various types of implants for humans or animals such as spinal implants (e.g., see FIGS. 1A-2D and 5A-6D)), corpectomy devices (e.g., see FIGS. 2C-2D), knee replacements (e.g., see FIG. 14), hip replacements (e.g., see FIG. 15), long bone reconstruction scaffolding (e.g., see FIG. 16), and cranio-maxifacial implants (e.g., see FIG. 17). Other implant uses are also contemplated.

[0043] As used herein a “truss” is a structure having one or more elongate struts connected at joints referred to as nodes. Trusses may include variants of a pratt truss, king post truss, queen post truss, town’s lattice truss, planar truss, space truss, and/or a vierendeel truss (other trusses

may also be used). Each unit (e.g., region having a perimeter defined by the elongate struts) may be referred to as a “truss unit.”

[0044] As used herein a “planar truss” is a truss structure where all of the struts and nodes lie substantially within a single two-dimensional plane. A planar truss, for example, may include one or more “truss units” where each of the struts is a substantially straight member such that the entirety of the struts and the nodes of the one or more truss units lie in substantially the same plane. A truss unit where each of the struts is a substantially straight member such that the entirety of the struts and the nodes of the truss units lie in substantially the same plane is referred to as a “planar truss unit.”

[0045] As used herein a “space truss” is a truss having struts and nodes that are not substantially confined in a single two-dimensional plane. A space truss may include two or more planar trusses (e.g., planar truss units) wherein at least one of the two or more planar trusses lies in a plane that is not substantially parallel to a plane of at least one or more of the other two or more planar trusses. A space truss, for example, may include two planar truss units adjacent to one another (e.g., sharing a common strut) wherein each of the planar truss units lie in separate planes that are angled with respect to one another (e.g., not parallel to one another).

[0046] As used herein a “triangular truss” is a structure having one or more triangular units that are formed by three straight struts connected at joints referred to as nodes. For example, a triangular truss may include three straight elongate strut members that are coupled to one another at three nodes to form a triangular shaped truss. As used herein a “planar triangular truss” is a triangular truss structure where all of the struts and nodes lie substantially within a single two-dimensional plane. Each triangular unit may be referred to as a “triangular truss unit.” A triangular truss unit where each of the struts is a substantially straight member such that the entirety of the struts and the nodes of the triangular truss units lie in substantially the same plane is referred to as a “planar triangular truss unit.” As used herein a “triangular space truss” is a space truss including one or more triangular truss units.

[0047] As used herein a “quadrilateral truss” is a structure having one or more quadrilateral units that are formed by four straight struts connected at joints referred to as nodes. For example, a quadrilateral truss may include four straight elongate strut members that are coupled to four nodes to form a quadrilateral shaped truss. As used herein a “planar quadrilateral truss” is a quadrilateral truss structure where all of the struts and nodes lie substantially within a single two-dimensional plane. Each quadrilateral unit may be referred to as a “quadrilateral truss unit.” A quadrilateral truss unit where each of the struts is a substantially straight member such that the entirety of the struts and the nodes of the quadrilateral truss units lie in substantially the same plane

is referred to as a “planar quadrilateral truss unit.” As used herein a “quadrilateral space truss” is a space truss including one or more quadrilateral truss units.

[0048] In various embodiments, the trusses 102 of web structure 101 may include one or more planar truss units (e.g., planar triangular truss units) constructed with straight or curved/arched members (e.g., struts) connected at various nodes. In some embodiments, the trusses 102 may be micro-trusses. A “micro-truss” may include a truss having dimensions sufficiently small enough such that a plurality of micro-trusses can be assembled or other wise coupled to one another to form a web structure having a small enough overall dimension (e.g., height, length and width) such that substantially all of the web structure can be inserted into an implant location (e.g., between two vertebra). Such a web structure and its micro-trusses can thus be employed to receive and distribute throughout the web structure loading forces of the surrounding tissue (e.g., vertebra, bone, or the like). In one embodiment, the diameters of the struts forming the micro-truss may be between about 0.25 millimeters (mm) and 5mm in diameter (e.g., a diameter of about 0.25mm, 0.5 mm, 0.6 mm, 0.7 mm, 0.8 mm, 0.9 mm, 1 mm, 2 mm, 3 mm, 4 mm, or 5 mm). In one embodiment, a micro-truss may have an overall length or width of less than about 1 inch (e.g., a length less than about 0.9 in, 0.8 in, 0.7 in, 0.6 in, 0.5 in, 0.4 in, 0.3 in, 0.2 in, 0.1 in).

[0049] As depicted, for example, in FIGS. 1A-1B, web structure 101 may extend throughout implant 100 (including the central portion of implant 100) to provide support throughout implant 100. Trusses 102 of implant 100 may thus support implant 100 against tensile, compressive, and shear forces. The web structure of trusses 102 may also reinforce implant 100 along multiple planes. The external truss structure may, for example, provide support against tensile and compressive forces acting vertically through the implant, and the internal web structure may provide support against tensile, compressive, and shear forces along the various planes containing the respective trusses. In some embodiments, the web structure includes trusses 102 that form a triangulated web structure with multiple struts (e.g., struts 103a-f) (struts are generally referred to herein as “struts 103”).

[0050] In one embodiment, web structure 101 of the implant 100 may include an internal web structure that is at least partially enclosed by an external truss structure. For example, in one embodiment, web structure 101 may include an internal web structure that includes a space truss having at least a portion of the space truss surrounded by an external truss structure that includes one or more planar trusses formed with a plurality of planar truss units that lie substantially in a single plane. FIG. 1A depicts an embodiment of implant 100 and web structure 101 that includes internal web structure 104 and an external truss structure 105. In the illustrated embodiment, internal web structure 104 includes a space truss defined by a plurality of planar truss units 106

coupled at an angle with respect to one another such that each adjacent truss unit is not co-planar with each adjacent truss units. Adjacent truss units may include two truss units that share a strut and the respective two nodes at the ends of the shared strut.

[0051] In one embodiment, external truss structure 105 includes a plurality of planar trusses that are coupled about an exterior, interior or other portion of the implant. For example, in the illustrated embodiment, the external truss structure 105 includes a series of planar trusses 107a,b that are coupled to one another. Each planar truss 107a,b includes a plurality of planar truss units 108 that are coupled to one another and lie substantially in the same plane. As depicted, planar truss 107a includes four triangular planar truss units 108 having a common vertex 110 and arranged to form a generally rectangular structure that lies in a single common plane 109. In other words, the four truss units are arranged to form a substantially rectangular structure having “X” shaped struts extend from one corner of the rectangular structure to the opposite corner of the rectangular structure. As depicted, the substantially rectangular structure may include a trapezoidal shape. As described in more detail below, the trapezoidal shape may be conducive to providing an implant including lordosis. Lordosis may include an angled orientation of surfaces (e.g., top and bottom) of an implant that provides for differences in thickness in anterior and posterior regions of the implant such that the implant is conducive for supporting the curvature of a vertebral column.

[0052] In one embodiment, the planar trusses that form the external truss are coupled to one another, and are aligned along at least one axis. For example, in FIG. 1A, planar truss section 107a is coupled to an adjacent planar truss 107b. Planer truss sections 107a,b are not parallel in all directions. Planar truss sections 107a,b are, however, arranged parallel to one another in at least one direction (e.g., the vertical direction between the top and the bottom faces of implant 100). For example, planar trusses 107a,b and the additional planar trusses are arranged in series with an angle relative to one another to form a generally circular or polygon shaped enclosure having substantially vertical walls defined by the planar trusses and the planar truss units arranged in the vertical direction.

[0053] In one embodiment, the external truss portion may encompass the sides, top, and/or bottom of the implant. For example, in one embodiment, the external truss portion may include a top region, side regions, and/or a bottom region. FIG. 1A depicts an embodiment of implant 100 wherein external truss portion 105 includes a top 111, bottom 112 and a side region 113. As described above, side region 113 includes a series of planar trusses arranged vertically to form a circular/polygon ring-like structure that completely or at least partially surrounds the perimeter of the space truss disposed in the central portion of implant 100. In the depicted embodiment, top

portion 111 of external truss structure 105 includes a plurality of truss units coupled to one another to form a planar truss that cover substantially all of the top region of internal web structure 104. In the illustrated embodiment, the top portion 111 spans entirely the region between top edges of the side portion 113 of external truss structure 105. In the illustrated embodiment, top portion 111 is formed from a single planar truss that includes a plurality of truss units that lie in substantially the same plane. In other words, the planar truss of top portion 111 defines a generally flat surface. Although difficult to view in FIG. 1, the underside of implant 100 may include the bottom portion 112 having a configuration similar to that of the top portion 111. In other embodiments, external truss structure 105 may include a partial side, top and/or bottom external truss portions. Or may not include one or more of the side, top and bottom external truss portions. For example, as described in more detail below, FIG. 2C depicts an embodiment of implant 100 that includes an internal web structure 104 that includes a space truss, and does not have an external truss structure.

[0054] In some embodiments, implant 100 may include a biocompatible material such as a titanium alloy (e.g., γ Titanium Aluminides), cobalt, chromium, stainless steel, Polyetheretherketone (PEEK), ceramics, etc. Other materials are also contemplated. In some embodiments, implant 100 may be made through a rapid prototyping process (e.g., electron beam melting (EBM) process) as further described below. Other processes are also possible (e.g., injection molding, casting, sintering, selective laser sintering (SLS), Direct Metal Laser Sintering (DMLS), etc). SLS may include laser-sintering of high-performance polymers such as that provided by EOS of North America, Inc., headquartered in Novi, Michigan, U.S.A. High-performance polymers may include various forms of PEEK (e.g., HP3 having a tensile strength of up to about 95 mega Pascal (MPa) and a Young's modulus of up to about 4400 MPa and continuous operating temperature between about 180 °C (356 °F) and 260 °C (500 °F)). Other materials may include PA 12 and PA 11 provided by EOS of North America, Inc.

[0055] As described above, in some embodiments the trusses may form a triangulated web structure with multiple struts 103. The web structure may include a pattern of geometrical building blocks. In some embodiments, the geometrical building blocks may include triangles. In some embodiments, the geometrical building blocks may include polyhedrons such as tetrahedrons, pentahedrons, hexahedrons, heptahedrons, pyramids, octahedrons, dodecahedrons, icosahedrons, and spherical fullerenes. In some embodiments, such as those described above, the space truss of the web structure may connect multiple midpoints of tetrahedron building blocks and include a regular pattern of tetrahedron blocks arranged adjacent one another. In some embodiments, the web structure may not include a pattern of geometrical building blocks. For

example, FIG. 9 illustrates an irregular pattern of struts 103 that may be used in implant 100. Other web structures are also contemplated.

[0056] FIGS. 3A-3B illustrate a web structure formed with triangular-shaped building blocks, according to an embodiment. The triangular shaped building blocks may form tetrahedrons 300a,b that may also be used as building blocks (other patterns from the triangles are also contemplated). Other building blocks are also contemplated (e.g., square-shaped building blocks). In some embodiments, a web structure may include a single tetrahedron, such as tetrahedron 300a or 300b alone or in combination with one or more other web structures. In some embodiments, web structure 313 may include two or more tetrahedrons 300a,b. Tetrahedron 300a may include four triangular faces in which three of the four triangles meet at each vertex. In some embodiments, two tetrahedrons 300a and 300b may be placed together at two adjacent faces to form web structure 313 with a hexahedron-shaped frame (including six faces). Hexahedron-shaped web structure 313 may include first vertex 301, second vertex 309, third vertex 303, fourth vertex 305, and fifth vertex 307. Common plane 311 may be shared by two tetrahedrons (e.g., common plane 311 may include third vertex 303, fourth vertex 305, and fifth vertex 307) to form a hexahedron with first vertex 301 and second vertex 309 spaced away from common plane 311. As depicted, the center portion of the triangular shaped building blocks may have a void region in their center that does not include any additional members (e.g., no members other than the struts forming the triangular shaped building blocks) extending there through.

[0057] As seen in FIG. 3B, in some embodiments, multiple hexahedron-shaped web structures 313 may be arranged in a side-by-side manner. Two web structures 313 of implant 100 may be connected via their first vertices 301a,b through strut 103r and connected via their second vertices 309a,b through strut 103t. Similarly, two web structures 313 may be connected via their first vertices 301c,d through strut 103p and connected via their second vertices 309c,d through strut 103s. Other connections are also possible. For example, web structures 313 may connect directly through side vertices (e.g., directly through corresponding vertices (such as vertices 303a,b) and/or share a common strut (such as strut 103u)) and/or through a side face (e.g., side faces 111a,b). Other struts are also shown (e.g., struts 103v, 103w).

[0058] FIG. 4A illustrates additional struts 103 (e.g., struts 103p and 103r) connecting the first vertices (represented respectively by 301a, 301b, 301c, and 301d) of four hexahedron-shaped web structures 313 in implant 100. FIG. 4B illustrates additional struts 103 (e.g., struts 103s and 103t) connecting second vertices 309 (represented respectively by 309a, 309b, 309c, and 309d) of four hexahedron-shaped web structures 313 in implant 100. In some embodiments, additional

struts 103 may also be used internally between one or more vertices of the web structures to form additional trusses (e.g., see web structures in FIGS. 1A-2B) (other structures are also possible).

[0059] In some embodiments, top surface 115a and bottom surface 115b of implant 100 may include triangles, squares, circles or other shapes (e.g., a random or custom design). Top and bottom surfaces 115a,b may be used to connect the top and bottom vertices of various geometrical building blocks used in the web structure of implant 100. For example, each vertex may be connected through struts to the neighboring vertices of other geometrical building blocks. Top surface 115a may include other strut networks and/or connections. In some embodiments, bottom surface 115b may mirror the top surface (and/or have other designs). In some embodiments, top surface 115a and bottom surface 115b may engage respective surfaces of two adjacent vertebrae when implant 100 is implanted.

[0060] As depicted in FIG. 1B, implant 100 may include lordosis (e.g., an angle in top and/or bottom surfaces 115a,b approximately in a range of 4 to 15 degrees (such as 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, or 15 degrees)) to further support the adjacent vertebrae when implanted. As described above, lordosis may include an angled orientation of surfaces (e.g., top and bottom) that provide for differences in thickness in the anterior and posterior portions of the implant such that the implant is conducive for supporting the curvature of a vertebral column. In the illustrated embodiment, the thickness of implant 100 is greater at or near the anterior portion 118 and lesser at or near the posterior portion 120 of the implant. In the illustrated embodiment, the side portions of external truss structure 105 are arranged substantially vertically, and the lordosis is formed by the angles of the top portion 111 and bottom portion 112 of external truss structure 105. For example, in the illustrated embodiment, top portion 111 and bottom portion 112 of external truss structure 105 are not perpendicular to the vertical plane defined by the side portion 113. Rather, the top portion 111 and bottom portion 112 are arranged with an acute angle relative to the vertical plane of side portion 113 at or near the anterior region 118 of implant 100 and with an obtuse angle relative to the vertical plane of side portion 113 at or near posterior region 120 of implant 100. As depicted, the vertical struts 103 that form the planar truss of side portion 113 of external truss structure 105 proximate posterior region 120 of implant 100 are shorter than struts 103 that form side portion 113 of external truss structure 105 proximate anterior region 118 of implant 100. In the illustrated embodiment, in which the vertical trusses 103 are substantially evenly spaced, the struts 103 forming the “X” cross members of the side planar trusses proximate the posterior region 120 of implant 100 are shorter than struts forming the “X” cross members of the side planar trusses proximate the anterior region 118 of implant 100. Other embodiments may include variations in the arrangement of the trusses to provide

various configurations of the implant. For example, in some embodiments only one or neither of the top and bottom external truss portions may be non-perpendicular to the side portions of the external truss proximate the anterior and posterior portions of the implant. Further, the side, top, and/or bottom portions may include multiple planar trusses angled relative to one another in any orientation. For example, the top or bottom portions may include four planar trusses, each formed of multiple truss units, such that the portion(s) includes a pyramidal like shape.

[0061] In some embodiments, the implant may not include lordosis. For example, FIGS. 2A-2B illustrate two views of an embodiment of an implant 200 without lordosis. In some embodiments, the top surface and bottom surface may not include connecting struts. For example, FIGS. 2C-2D illustrate two views of implant 250 without outer struts (e.g., without external truss portions formed of planar trusses). In the illustrated embodiment, implant 250 includes internal web structure 104 (e.g., a space truss) and does not include an external truss structure. For example, in the illustrated embodiment, the exterior faces of implant 250 are defined by a plurality of truss units that are angled relative to each of its adjacent truss units. The relative alignment of the truss units results in a non-planar exterior that includes a plurality of pointed junctions. The pointed junctions (e.g., pointed junction 201) may operate to dig into the surrounding bone to hold the implant in place (for example, if the implant is being used in a corpectomy device).

[0062] FIGS. 5A-5C illustrate progressive sectioned views of implant 100 showing the internal structure of implant 100, according to an embodiment. FIG. 5A illustrates a sectioned view of a lower portion of implant 100. Bottom surface 105b is shown with various struts (e.g., struts 103) extending upward from bottom surface 105b. FIG. 5B illustrates a sectioned view approximately mid-way through implant 100. Struts, such as struts 103e, 103f, shared by various stacked tetrahedrons in the web structure are shown. Some struts extend through central portion 501a and/or 501b of implant 100. FIG. 5B also shows central portions 501a,b of implant 100. In some embodiments, central portion 501a may include a rectangular region that has a width of approximately 50% of the implant width, a height of approximately 50% of the implant height, and a length of approximately 50% of the implant length and located in the center of implant 100. In some embodiments, central portion 501b may encompass a region (e.g., a spherical region, square region, etc.) of approximately a radius of approximately 1/8 to 1/4 of the width of implant 100 around a position located approximately at one half the width, approximately one half the length, and approximately one-half the height of implant 100 (i.e., the center of implant 100). Other central portions are also contemplated. For example, the central portion may include a square region with a length of one of the sides of the square region approximately 1/4 to 1/2 the

width of implant 100 around a position approximately at one half the width, approximately one half the length, and approximately one half the height of the implant. An example height 502a, width 502b, and length 502c, is shown in FIG. 5D. In some embodiments, the height may be up to about 75mm or more. In some embodiments, such as those used for long bone reconstruction, the width and/or length could be approximately 7 inches or longer. In some embodiments, the width, length, and/or height may vary along implant 100 (e.g., the height may vary if the implant includes lordosis). The height may be taken at one of the opposing sides, the middle, and/or may be an average of one or more heights along the length of implant 100. The web structure may extend through central portion 501a,b of the implant (e.g., at least one strut of the web structure may pass at least partially through central portion 501a,b). FIG. 5C illustrates another sectioned view showing sectioned views of top tetrahedrons in the web structure. FIG. 5D shows a complete view of implant 100 including top surface 115a with vertices 301a-d.

[0063] FIGS. 6A-6D illustrate alternate embodiments of implant 100. In some embodiments, different sections of the hexahedron-shaped geometric design may be used. For example, as seen in FIG. 6A, the bottom half of the hexahedron-shaped geometric design may be used (primarily including the lower tetrahedron structures). If using the bottom half of the design, design 600 may be expanded proportionately to have similar overall dimensions as the hexahedron-shaped geometric design (e.g., the tetrahedrons may be expanded to approximately twice the height of the tetrahedrons in the hexahedron-shaped geometric design to give design 600 a height approximately the same as the hexahedron-shaped geometric design). In some embodiments, design 600 may also be angled (e.g., on top surface 601a and/or bottom surface 601b) to provide design 600 with lordosis to, in some embodiments, have a better fit between the vertebral endplates. Top surface 601a and/or bottom surface 601b may also include struts to connect nodes of design 600 (e.g., see the strut network on the top surface in FIG. 6a). Other patterns of struts for top surface 601a and/or bottom surface 601b may also be used. In some embodiments, design 600 may not include negative angles between struts and may thus be easier to create through a casting or molding process.

[0064] FIGS. 6C-6D illustrate another alternate embodiment of implant 100. In some embodiments, approximately the middle 40 to 60 percent of the hexahedron-shaped geometric design may be used. For example, if an overall height of the hexahedron-shaped geometric design is approximately 37 mm, approximately the bottom 10 mm and approximately the top 10 mm of the design may be removed and approximately the middle 17 mm of the design may be used for the implant. Middle portion design 650 may then be expanded proportionately such that the approximate height of the expanded design may be approximately 37 mm (or a different

height as needed). Top surface 651a and bottom surface 651b may include a network of struts (e.g., see the struts on top surface 651a of FIG. 6C) (other networks of struts are also contemplated). Other portions of the design for the implant are also contemplated (e.g., the top half of the design shown in FIG. 1A, the bottom half of the design shown in FIG. 1A, etc). Design portions may be proportionately expanded to meet specified dimensions (e.g., specified height, width, and length). In some embodiments, the amount of struts may be reduced or material in the implant may be redistributed so that some struts may have a larger diameter and some may have a smaller diameter (e.g., the different diameters may reinforce against different directional forces). In some embodiments, a partial-design cage may be used (e.g., with half of the web structure so that the structure includes a tetrahedron. Further, in some embodiments, the implant may include angled surfaces (e.g., an angled top surface 651a and/or angled bottom surface 651b) to provide lordosis for implants to be implanted between the vertebral endplates.

[0065] In some embodiments, the web structure of implant 100 may distribute forces throughout implant 100 when implanted. For example, the connecting struts of the web structure may extend throughout the core of implant 100, and the interconnectivity of struts 103 may disperse the stress of compressive forces throughout implant 100 to reduce the potential of stress risers (the distribution of forces throughout implant 100 may prevent concentration of stress on one or more portions of the vertebrae that may otherwise result in damage to the vertebrae).

[0066] In some embodiments, the web structure of implant 100 (e.g., the external and internal struts of implant 100) may also provide surface area for bone graft fusion. For example, the web structure extending throughout implant 100 may add additional surface areas (e.g., on the surface of the struts making up implant 100) to fuse to the bone graft material and prevent bone graft material from loosening or migrating from implant 100. In some embodiments, the web structure may also support bone in-growth. For example, when implanted, adjacent bone (e.g., adjacent vertebrae if the implant is used as a spinal implant) may grow over at least a portion of struts 103 of implant 100. The bone growth and engagement between the bone growth and implant 100 may further stabilize implant 100. In some embodiments, the surfaces of implant 100 may be formed with a rough surface to assist in bone in-growth adhesion.

[0067] In some embodiments, struts 103 may have a diameter approximately in a range of about 0.025 to 5 millimeters (mm) (e.g., 1.0 mm, 1.5 mm, 3 mm, etc). Other diameters are also contemplated (e.g., greater than 5 mm). In some embodiments, the struts may have a length approximately in a range of 0.5 to 20 mm (e.g., depending on the implant size needed to, for example, fit a gap between vertebral endplates). As another example, struts may have a length approximately in a range of 30-40 mm for a hip implant. In some embodiments, the reduced

strut size of the web structure may allow the open cells in implant 100 to facilitate bone growth (e.g., bone may grow through the open cells once implant 100 is implanted in the body). Average subsidence for implants may be approximately 1.5 mm within the first 3 weeks post op (other subsidence is also possible (e.g., approximately between 0.5 to 2.5 mm)). A strut size that approximately matches the subsidence (e.g., a strut size of approximately 1.5 mm in diameter and a subsidence of approximately 1.5 mm) may result in a net 0 impedance (e.g., the bone growth growing around the struts) after implant 100 has settled in the implanted position. The net 0 impedance throughout the entire surface area of the implant/vertebrae endplate interface may result in a larger fusion column of bone that may result in more stable fusion. Other fusion column sizes are also contemplated. The configuration of the implant 100 may redistribute the metal throughout the implant 100. In some embodiments, a rim may not be included on the implant 100 (in some embodiments, a rim may be included). The resulting bone growth (e.g., spinal column) may grow through the implant 100.

[0068] In some embodiments, greater than 50% of the interior volume of implant 100 may be open. In some embodiments, greater than 60%, greater than 70%, and/or greater than 80% of implant 100 may be open (e.g., 95%). In some embodiments, the open volume may be filled with bone growth material. For example, cancellous bone may be packed into an open/internal region of implant 100.

[0069] In some embodiments, at least a portion of the surfaces of implant 100 may be coated/treated with a material intend to promote bone growth and/or bone adhesion and/or an antimicrobial agent to prevent infections. For example, in some embodiments, the surface of the struts (e.g., struts 103 forming the web structure) may be coated with a biologic and/or a bone growth factor. In some embodiments, a biologic may include a coating, such as hydroxyapatite, bone morphogenetic protein (BMP), insulinlike growth factors I and II, transforming growth factor-beta, acidic and basic fibroblast growth factor, platelet-derived growth factor, and/or similar bone growth stimulant that facilitates good biological fixation between the bone growth and a surface of the implant. In some embodiments, a bone growth factor may include a naturally occurring substance capable of stimulating cellular growth, proliferation and cellular differentiation (e.g., a protein or steroid hormone).

[0070] In some embodiments, a biologic and/or growth factor may be secured to a central region of implant 100. For example, in some embodiments, a biologic or growth factor may be provided on at least a portion of a strut that extends through central portion 501a and/or 501b of implant 100. Such an embodiment may enable the delivery of a biologic and or a growth factor to a central portion of an implant. For example, the biologic or growth factor may be physically

secured to a strut in a central portion of implant 100 as opposed to being packed into an open volume that does not include a strut provided therein for the physical attachment of the biologic and/or growth factor.

[0071] As implant 100 settles into the implant site, subsidence may place additional pressure on the bone graft material (which may already be under compressive forces in implant 100) and act to push the bone graft material toward the sides of implant 100 (according to Boussinesq's theory of adjacent material, when a force is applied to a member that is adjacent to other materials (such as sand, dirt, or bone graft material) the force against the member creates a zone of increased pressure (e.g., 60 degrees) in the adjacent material). Struts 103 of the web structure may resist bone graft material protrusion from the sides of the web structure and may increase the pressure of the bone graft material. Bone graft material may need to be implanted in a higher-pressure environment to create an environment conducive to strong bone growth (e.g., according to Wolf's law that bone in a healthy person or animal will adapt to the loads it is placed under). The web structure may thus increase the chance of stronger fusion.

[0072] FIG.7A illustrates a web structure formed with two pyramids, according to an embodiment. The geometric building blocks for implant 100 include pyramids. For example, top/upper pyramid 705a and bottom/lower pyramid 705b may be joined to form a octahedron building block 703. The octahedron building blocks 703 may be joined, for example, at a face (e.g., a base 706 of the top and bottom pyramids 705a and 705b) by sharing a surface, etc. In one embodiment one or both of top and bottom pyramid 705a,b may include a square pyramid. The resulting octahedron thus includes two opposing pyramid shaped truss structures that share a common square shaped truss unit at their base (e.g., where the two bases of the pyramids meet).

[0073] It is further noted that the geometric building block may include one or more additional struts extending through an interior region defined by the faces of the building blocks. For example, in the illustrated embodiment, the octahedron building block formed from top and lower pyramids 705a,b include two struts 103a extending diagonally between opposing vertices of the face (e.g., the square shaped truss unit) shared by top and lower pyramids 705a,b, and having an intersection 710. Accordingly, the opposing vertices are directly connected by one or more struts arranged in a substantially straight line between each pair of the opposing vertices. In one embodiment, struts 103a may be formed from four separate strut sections that extend from each respective vertex to intersection 710. The illustrated embodiment also includes an additional central strut 103b that extends between vertices 701, 709 of top and bottom pyramids 705a,b, and that intersects struts 103a at or near intersection 710. In one embodiment, strut 103b may be formed from one or two separate strut sections that extend from each respective vertex

701, 709 of top and bottom pyramids 705a,b to intersection 710. Accordingly, the opposing vertices of the octahedron that do not lie in the common face (e.g. base) of the two pyramids 705a,b forming the octahedron are directly connected by one or more struts arranged in a substantially straight line between the opposing vertices. Other embodiments may include any combination of struts 103a,b. For example, one embodiment may include only one or two of struts 103a extending between opposing vertices of the square shaped common truss unit and without strut 103b. For example, one embodiment may include only two opposing vertices of the square shaped common truss unit being connected to one another via a strut. One embodiment may include only strut 103b extending between the opposing vertices of the octahedron without struts 103a.

[0074] FIG. 7B illustrates a web structure formed with two hexahedrons, according to an embodiment. The geometric building blocks for implant 100 include hexahedrons. For example, top/upper hexahedron 705a and bottom/lower hexahedron 705b may be joined to form a dodecahedron building block 703. The dodecahedron building blocks 703 may be joined, for example, at a face (e.g., their bases) by sharing a side surface, etc. Embodiments may include additional members, such as struts 103a,b that extend between vertices of the hexahedron 705a,b in a manner similar to that described with respect to FIG. 7A.

[0075] FIG. 7C illustrates a web structure formed with two dodecahedrons, according to an embodiment. For example, top/upper dodecahedron 705a and bottom/lower dodecahedron 705b may be joined to form a 22-sided polyhedron building block 705. The 22-sided polyhedron building blocks 705 may be joined, for example, at a face by sharing a side surface, etc. Embodiments may include additional members, such as struts 103a,b that extend between vertices of the dodecahedrons 700a,b in a manner similar to that described with respect to FIG. 7A.

[0076] Web structures formed from other truss configurations are also contemplated. For example, the trusses may include a series of packing triangles, a two-web truss, a three-web truss, etc. Further, the web structure for implant 100 may include one or more trusses as described in U.S. Pat. No. 6,931,812 titled “Web Structure and Method For Making the Same”, which issued Aug. 23, 2005.

[0077] FIG. 10 illustrates a flowchart of a method for making implant 100. In some embodiments, implant 100 may be made through rapid prototyping (e.g., electron beam melting, laser sintering, etc). It should be noted that in various embodiments of the methods described below, one or more of the elements described may be performed concurrently, in a different

order than shown, or may be omitted entirely. Other additional elements may also be performed as desired. In some embodiments, a portion or the entire method may be performed automatically by a computer system.

[0078] At 1001, a three dimensional model of implant 100 may be generated and stored in a storage medium accessible to a controller operable to control the implant production process. At 1003, a layer of material (e.g., a powder, liquid, etc.) may be applied to a support. In some embodiments, the powder may include γ TiAl (γ Titanium Aluminides) which may be a high strength/low weight material. Other materials may also be used. The powder may be formed using a gas atomization process and may include granules with diameters approximately in a range of 20 to 200 micrometers (μm) (e.g., approximately 80 μm). The powder may be delivered to the support through a distributor (e.g., delivered from a storage container). The distributor and/or the support may move during distribution to apply a layer (e.g., of powder) to the support. In some embodiments, the layer may be approximately a uniform thickness (e.g., with an average thickness of 20 to 200 micrometers (μm)). In some embodiments, the distributor and support may not move (e.g., the material may be sprayed onto the support). At 1005, the controller may move an electron beam relative to the material layer. In some embodiments, the electron beam generator may be moved, and in some embodiments the support may be moved. If the material is γ TiAl, a melting temperature approximately in a range of 1200 to 1800 degrees Celsius (e.g., 1500 degrees Celsius) may be obtained between the electron beam and the material. At 1007, between each electron beam pass, additional material may be applied by the distributor. At 1009, the unmelted material may be removed and implant 100 may be cooled (e.g., using a cool inert gas). In some embodiments, the edges of the implant may be smoothed to remove rough edges (e.g., using a diamond sander). In some embodiments, the implant may include rough edges to increase friction between the implant and the surrounding bone to increase adhesion of the implant to the bone.

[0079] Other methods of making implant 100 are also contemplated. For example, implant 100 may be cast or injection molded. In some embodiments, multiple parts may be cast or injection molded and joined together (e.g., through welding, melting, etc). In some embodiments, individual struts 103 forming implant 100 may be generated separately (e.g., by casting, injection molding, etc.) and welded together to form implant 100. In some embodiments, multiple implants of different sizes may be constructed and delivered in a kit. A medical health professional may choose an implant (e.g., according to a needed size) during the surgery. In some embodiments, multiple implants may be used at the implant site.

[0080] FIG. 11 illustrates a flowchart of a method for implanting a spinal implant, according to an embodiment. It should be noted that in various embodiments of the methods described below, one or more of the elements described may be performed concurrently, in a different order than shown, or may be omitted entirely. Other additional elements may also be performed as desired. In some embodiments, a portion or the entire method may be performed automatically by a computer system.

[0081] At step 1301, an intersomatic space may be accessed. For example, an anterior opening may be made in a patient's body for an anterior lumbar inter-body fusion (ALIF) approach or a posterior opening may be made for a posterior lumbar inter-body fusion (PLIF) approach. At 1303, at least a portion of the intersomatic space may be excised to form a cavity in the intersomatic space. At 1305, the implant may be inserted into the cavity in the intersomatic space. In some embodiments, handler 1100 may be used to grip implant 100. In some embodiments, force may be applied to the implant (e.g., through a hammer) to insert the implant into the cavity. After placement of implant 100, trigger 1109 on handler 1100 may be released to release implant 100. At 1307, before and/or after insertion of the implant, the implant and/or space in the cavity may be packed with bone graft material. At 1309, the access point to the intersomatic space may be closed (e.g., using sutures).

[0082] In some embodiments, the implant may be customized. For example, three dimensional measurements and/or shape of the implant may be used to construct an implant that distributes the web structure throughout a three-dimensional shape design. As noted in FIG. 10, the three-dimensional shape design of the implant may be entered into a computer system/controller that may control the electron beam melting process. In some embodiments, the truss design and orientation may be preset or predetermined by the computer system/controller. In some embodiments, a user may select the truss design to use (e.g., one or more of truss designs shown in FIGS. 3A, 7A, or 8A-9) and/or may select the orientation of the trusses in the implant. In some embodiments, the user may enter the outer dimensions of the three dimensional shape and the computer system/controller may generate a three-dimensional design that includes the truss design and orientation. The computer system/controller may generate the three-dimensional design by providing a uniform distribution of the truss design throughout a three-dimensional shape with the outer dimensions provided by the user. In some embodiments, the heights and widths of the trusses used in the design may be proportional to the overall height and width of the three-dimensional shape (e.g., the trusses may have heights approximately equal to $\frac{1}{2}$ the overall height and a width of approximately $\frac{1}{16}$ the overall width). Other heights and widths are also

contemplated. In some embodiments, the user may provide the height and width and/or the computer system/controller may have default heights and widths to use.

[0083] Embodiments of a subset or all (and portions or all) of the above may be implemented by program instructions stored in a memory medium or carrier medium and executed by a processor (e.g., a processor on the controller operable to control the implant production process). A memory medium may include any of various types of memory devices or storage devices. The term “memory medium” is intended to include an installation medium, e.g., a Compact Disc Read Only Memory (CD-ROM), floppy disks, or tape device; a computer system memory or random access memory such as Dynamic Random Access Memory (DRAM), Double Data Rate Random Access Memory (DDR RAM), Static Random Access Memory (SRAM), Extended Data Out Random Access Memory (EDO RAM), Rambus Random Access Memory (RAM), etc.; or a non-volatile memory such as a magnetic media, e.g., a hard drive, or optical storage. The memory medium may comprise other types of memory as well, or combinations thereof. In addition, the memory medium may be located in a first computer in which the programs are executed, or may be located in a second different computer that connects to the first computer over a network, such as the Internet. In the latter instance, the second computer may provide program instructions to the first computer for execution. The term “memory medium” may include two or more memory mediums that may reside in different locations, e.g., in different computers that are connected over a network.

[0084] In some embodiments, a computer system at a respective participant location may include a memory medium(s) on which one or more computer programs or software components according to one embodiment of the present invention may be stored. For example, the memory medium may store one or more programs that are executable to perform the methods described herein. The memory medium may also store operating system software, as well as other software for operation of the computer system.

[0085] In some embodiments, a truss/web structure may be disposed on at least a portion of an implant to facilitate coupling of the implant to an adjacent structure. For example, where an implant is implanted adjacent a bony structure, one or more truss structures may be disposed on and/or extend from a surface (e.g., an interface plate) of the implant that is intended to contact, and at least partially adhere to, the bony structure during use. In some embodiments, such as those including an intervertebral implant disposed between the end plates of two adjacent vertebrae during, one or more truss structures may be disposed on a contact surface of the intervertebral implant to facilitate bone growth that enhances coupling of the intervertebral implant to the bony structure. For example, a truss structure may include one or more struts that

extend from the contact surface to define an open space for bone growth therethrough, thereby enabling bone through growth to interlock the bone structure and the truss structure with one another to couple the implant to the bony structure at or near the contact face. Such interlocking bone through growth may inhibit movement between the implant and the bony structure which could otherwise lead to loosening, migration, subsidence, or dislodging of the implant from the intended position. Similar techniques may be employed with various types of implants, including those intended to interface with tissue and/or bone structures. For example, a truss structure may be employed on a contact surface of knee implants, in a corpectomy device, in a hip replacement, in a knee replacement, in a long bone reconstruction scaffold, or in a cranio-maxifacial implant hip implants, jaw implant, an implant for long bone reconstruction, foot and ankle implants, shoulder implants or other joint replacement implants or the like to enhance adherence of the implant to the adjacent bony structure or tissue.

[0086] A prosthetic implant used in a ball-and socket type joint replacement includes a cup, and a ball component. Ball-and socket type joint replacement are generally used for shoulder and hip replacement surgery. An embodiment of a ball component of a ball-and-socket type prosthesis is shown in FIG. 12. Ball component 3600 includes a head 3610 and a stem 3620. Head 3610 has a shape and size to form a ball and socket joint with a corresponding cup component. A collar 3630 couples the head 3610 to the stem 3620. Stem 3620 includes a web structure 3640 comprising a space truss comprising two or more planar truss units having a plurality of struts joined at nodes. Web structure 3640 may take on any specific design described herein. Extending from collar 3630 through web structure 3640 is a compression screw 3655 and a bone screw 3660. Clamp 3650 is coupled to compression screw 3655. Clamp 3650 together with collar 3630 couple to the outer surface of the bone to couple the ball component to the bone.

[0087] FIG. 13 depicts the ball-and-socket prosthesis implanted in a subject. Cup component 3700 is placed into the stationary portion 3710 of the patient (e.g., shoulder or hip). Ball component 3600 is placed onto and into the moving portion 3720 of the patient (e.g., arm or leg bone) as shown. Ball component 3600 is coupled to the bone by forming a cavity in a portion of the bone that is capable of accepting the web structure 3640. Two bores are also formed in the bone that allow clamp rod 3655 and bone screw 3660 to pass through the bone. After the appropriate bone openings have been made, web structure 3640 is placed into the cavity and compression screw 3655 and bone screw 3660 are passed through the bone as shown. Clamp 3650 is tightened against the bone, drawing collar 3630 against the opposing surface of the bone. Together clamp 3650 and collar 3630 secure the ball component onto the bone. Bone screw

3660, and an additional bone screw 3670 are placed into the bone to secure the ball component onto the bone.

[0088] FIG. 14 depicts an alternative ball-and-socket prosthesis implanted in a subject. Cup 3700 is placed into the stationary portion 3710 of the patient (e.g., shoulder or hip). Ball component 3600 is placed onto and into the moving portion 3720 of the patient (e.g., arm or leg bone) as shown. Ball component 3600 includes a stem that includes one or more truss structures 3800. Truss structures 3800 include three or more struts 3810 joined at a node 3820, wherein the one or more truss structures are configured to interface with bone tissue 3620. Two bores are also formed in the bone that allow compression screw 3655 and bone screw 3660 to pass through the bone. After the appropriate bone openings have been made, truss structures 3800 are embedded into the bone and compression screw 3655 and bone screw 3660 are passed through the bone as shown. Clamp 3650 is tightened against the bone, drawing collar 3630 against the opposing surface of the bone. Together clamp 3650 and collar 3630 secure the ball component onto the bone. Bone screw 3660, and an additional bone screw 3670 are placed into the bone to secure the ball component onto the bone. Truss structures 3800 provide a surface for bone growth to secure the ball component to the bone.

[0089] Use of a web structure or one or more truss structures as a part of the femoral component allows the implant to be absorbed into the bone as the bone is regenerated. Thus the femoral component is integrated into the femur bone, making failure of the hip replacement less likely.

[0090] In accordance with the above descriptions, in various embodiments, an implant may include a web structure. The web structure for the implant may include a micro truss design. In some embodiments, the micro truss design may include a web structure with multiple struts. Other web structures are also contemplated. The web structure may extend throughout the implant (including a central portion of the implant). The web structure may thus reinforce the implant along multiple planes (including internal implant load bearing) and provide increased area for bone graft fusion. The web structure may be used in implants such as spinal implants, corpectomy devices, hip replacements, knee replacements, long bone reconstruction scaffolding, and cranio-maxifacial implants. Other implant uses are also contemplated. In some embodiments, the web structure for the implant may include one or more geometric objects (e.g., polyhedrons). In some embodiments, the web structure may not include a pattern of geometrical building blocks (e.g., an irregular pattern of struts may be used in the implant). In some embodiments, the web structure may include a triangulated web structure including two or more tetrahedrons. A tetrahedron may include four triangular faces in which three of the four triangles meet at each vertex. The web structure may further include two tetrahedrons placed together at two adjacent faces to form a web structure with a hexahedron-shaped frame (including six faces). In some embodiments, multiple hexahedron-shaped web structures may be arranged in a

side-by-side manner. The web structures may connect directly through side vertices (e.g., two or more hexahedron-shaped web structures may share a vertex). In some embodiments, the web structure may be angled to provide lordosis to the implant.

[0092] Further modifications and alternative embodiments of various aspects of the invention may be apparent to those skilled in the art in view of this description. For example, although in certain embodiments, struts have been described and depicts as substantially straight elongated members, struts may also include elongated members curved/arched along at least a portion of their length. Accordingly, this description is to be construed as illustrative only and is for the purpose of teaching those skilled in the art the general manner of carrying out the invention. It is to be understood that the forms of the invention shown and described herein are to be taken as embodiments. Elements and materials may be substituted for those illustrated and described herein, parts and processes may be reversed, and certain features of the invention may be utilized independently, all as would be apparent to one skilled in the art after having the benefit of this description of the invention. Changes may be made in the elements described herein without departing from the spirit and scope of the invention as described in the following claims. Furthermore, it is noted that the word “may” is used throughout this application in a permissive sense (i.e., having the potential to, being able to), not a mandatory sense (i.e., must). The term “include”, and derivations thereof, mean “including, but not limited to”. As used in this specification and the claims, the singular forms “a”, “an” and “the” include plural referents unless the content clearly indicates otherwise. Thus, for example, reference to “a strut” includes a combination of two or more struts. The term “coupled” means “directly or indirectly connected”.

CLAIMS

1. A ball component of a ball-and-socket joint prosthesis comprising a spherical head, a stem, and a collar coupling the head to the stem, wherein the stem comprises a web structure, the web structure comprising a space truss comprising a plurality of planar truss units having a plurality of struts joined at nodes, wherein the web structure is configured to interface with bone tissue, and wherein the web structure extends throughout the central portion of the stem, and

wherein the ball component further comprises:

- a compression screw extending from the collar through the web structure and/or
- a bone screw extending from the collar through the web structure.

2. The ball component of claim 1, wherein the plurality of planar truss units comprise a planar triangular truss unit having three substantially straight struts and three nodes in a triangular configuration.

3. The ball component of claim 1, wherein the plurality of planar truss units comprise a planar quadrilateral truss unit having four substantially straight struts and four nodes in a quadrilateral configuration.

4. The ball component of any one of claims 1 to 3, wherein the plurality of planar truss units are coupled to one another such that a planar truss unit lies in a plane that is not substantially parallel to a plane of an adjacent planar truss unit that shares at least one strut.

5. The ball component of any one of claims 1 to 4, wherein a plurality of planar truss units define an exterior surface of the web structure.

6. The ball component of any one of claims 1 to 5, wherein the struts that create the space truss comprises a biologic, growth factor or antimicrobial coupled thereto.

7. A ball-and-joint prosthesis comprising:

- a cup; and
- a ball component as described in any one of claims 1 to 6.

1 / 20

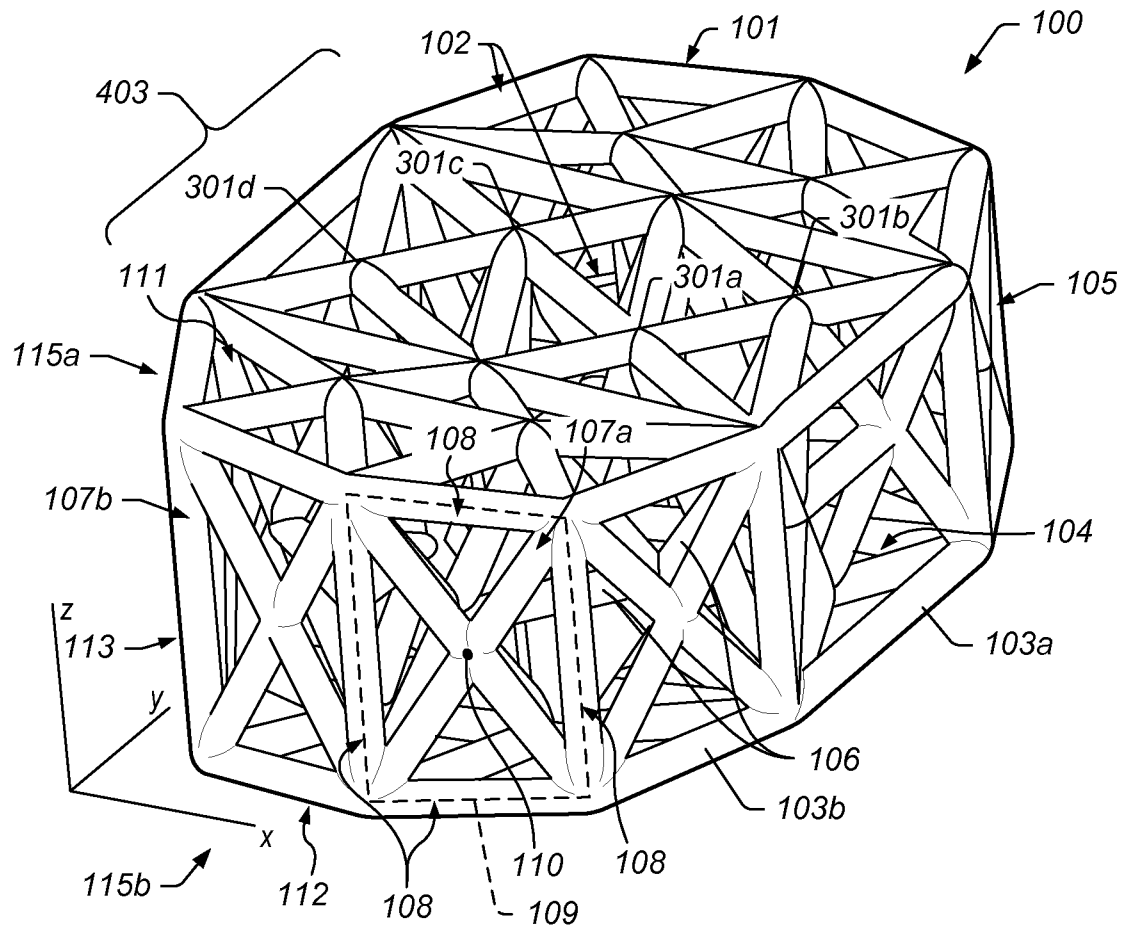


FIG. 1A

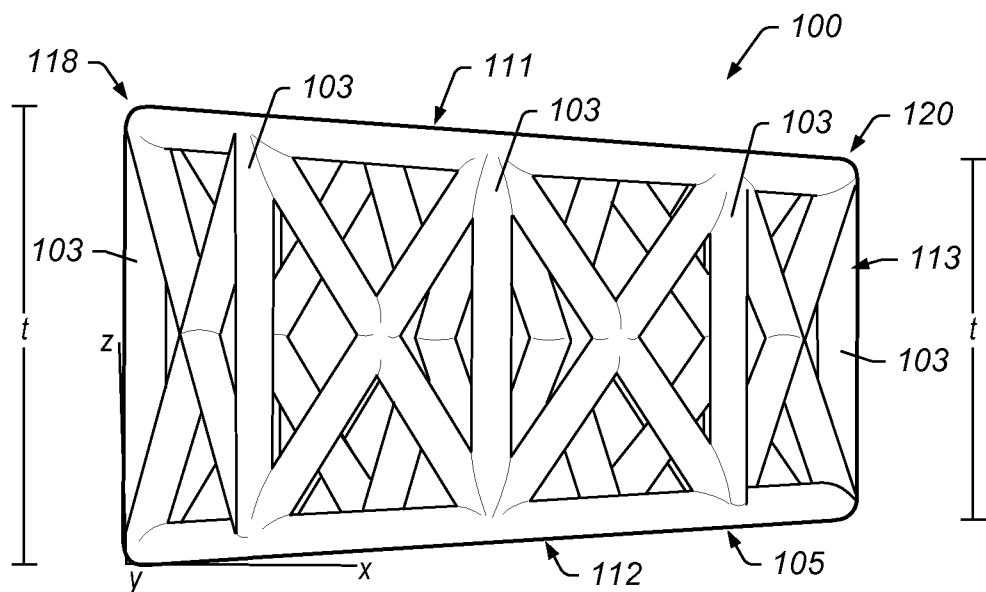


FIG. 1B

2 / 20

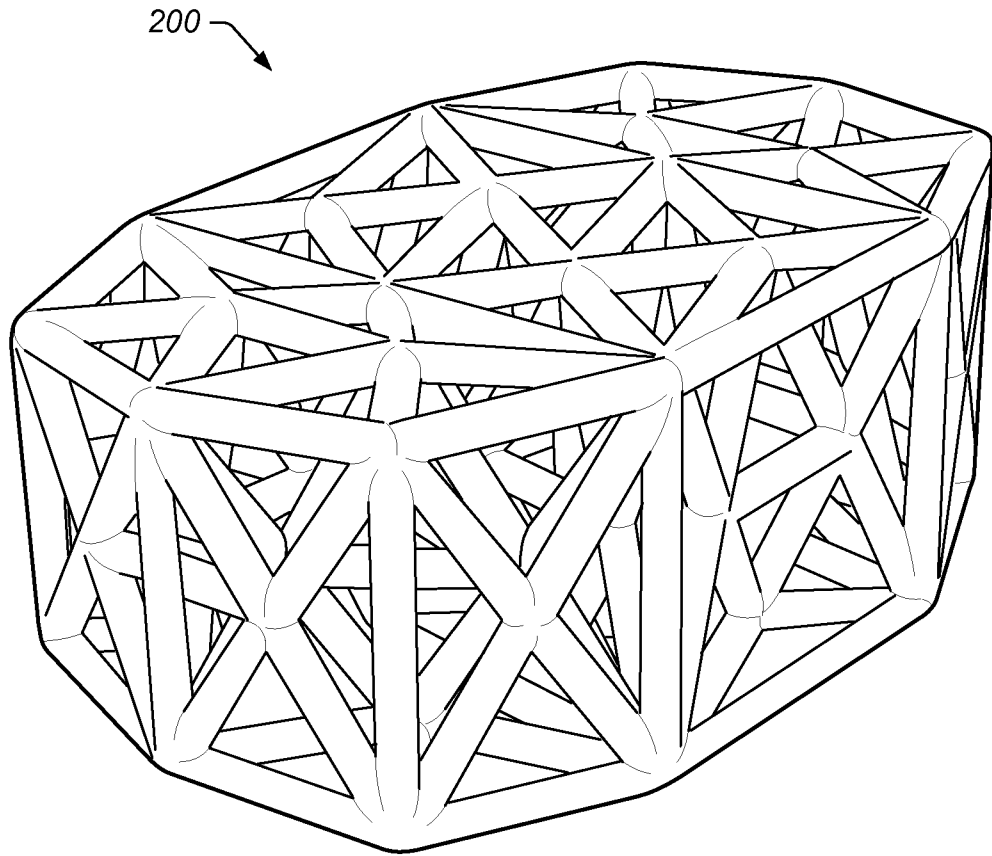


FIG. 2A

3 / 20

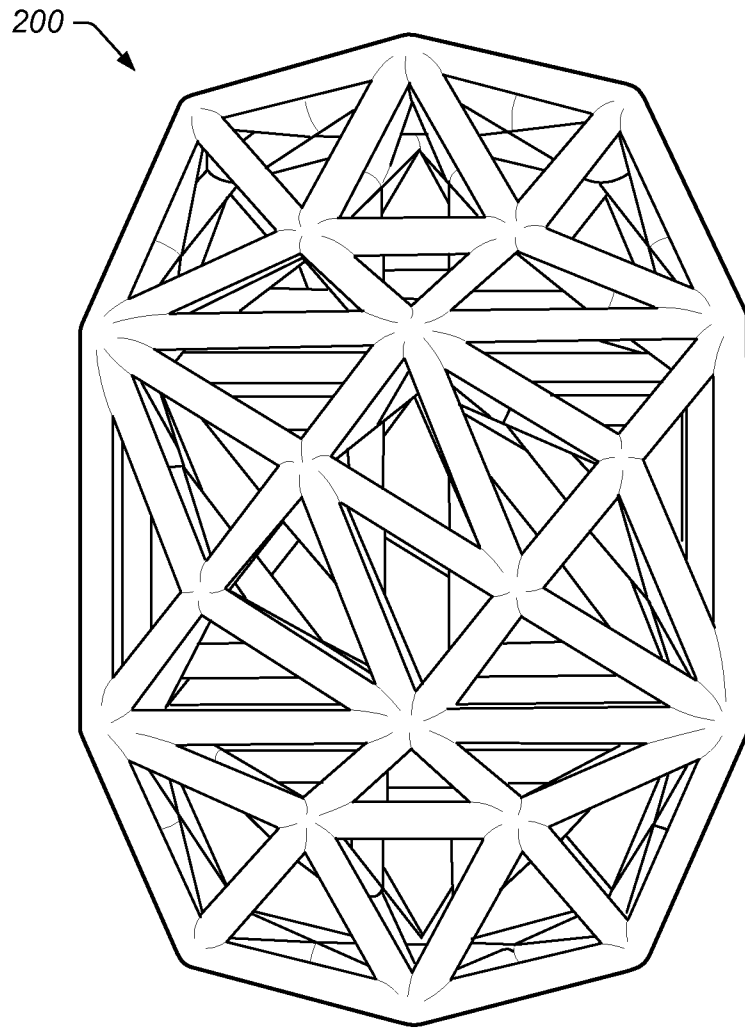


FIG. 2B

4 / 20

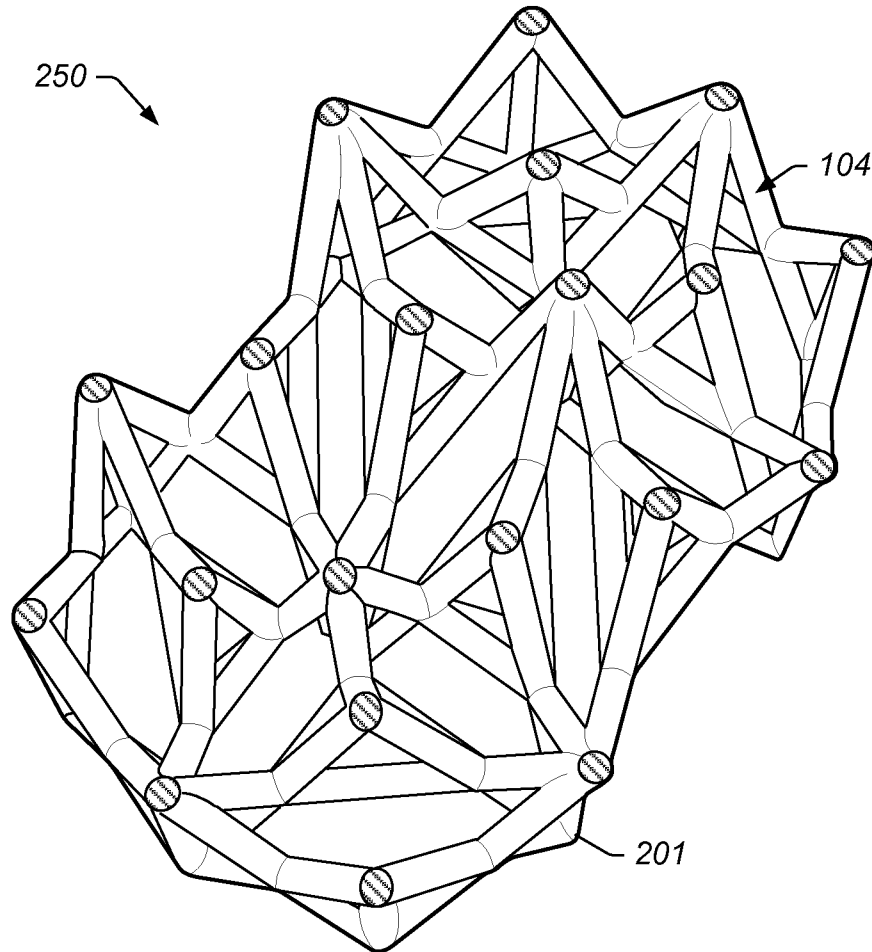


FIG. 2C

5 / 20

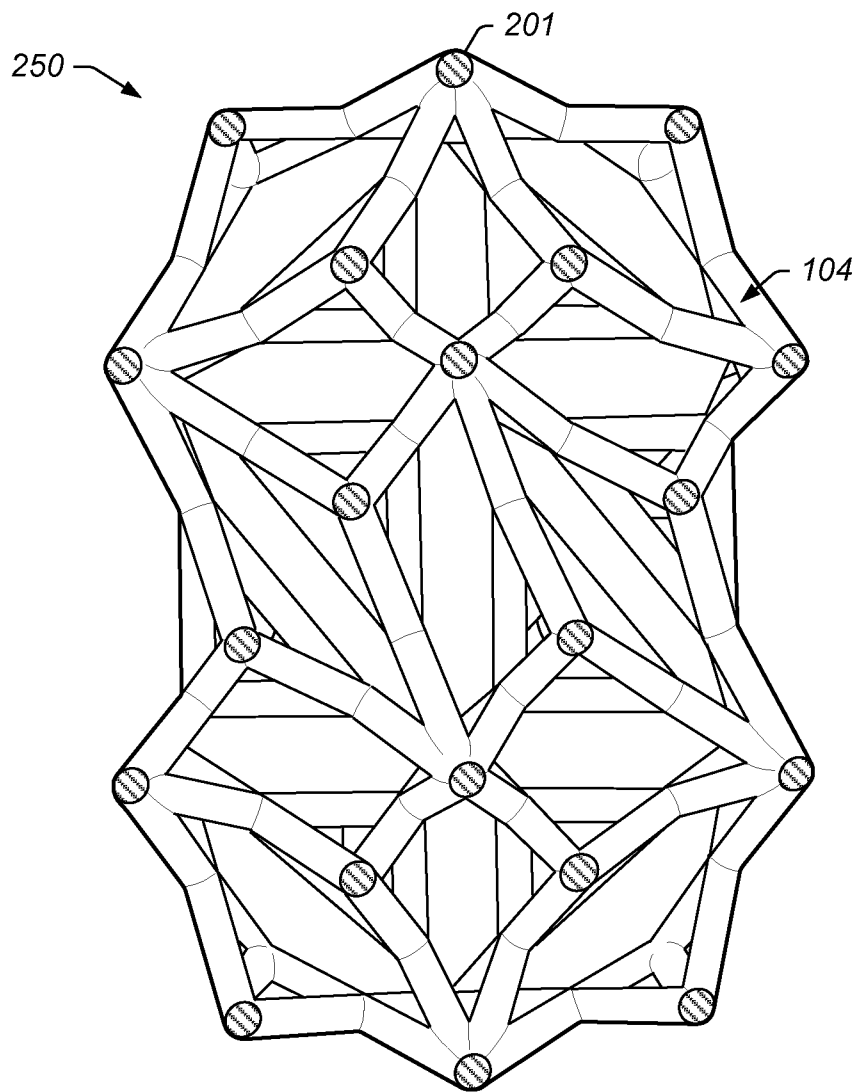
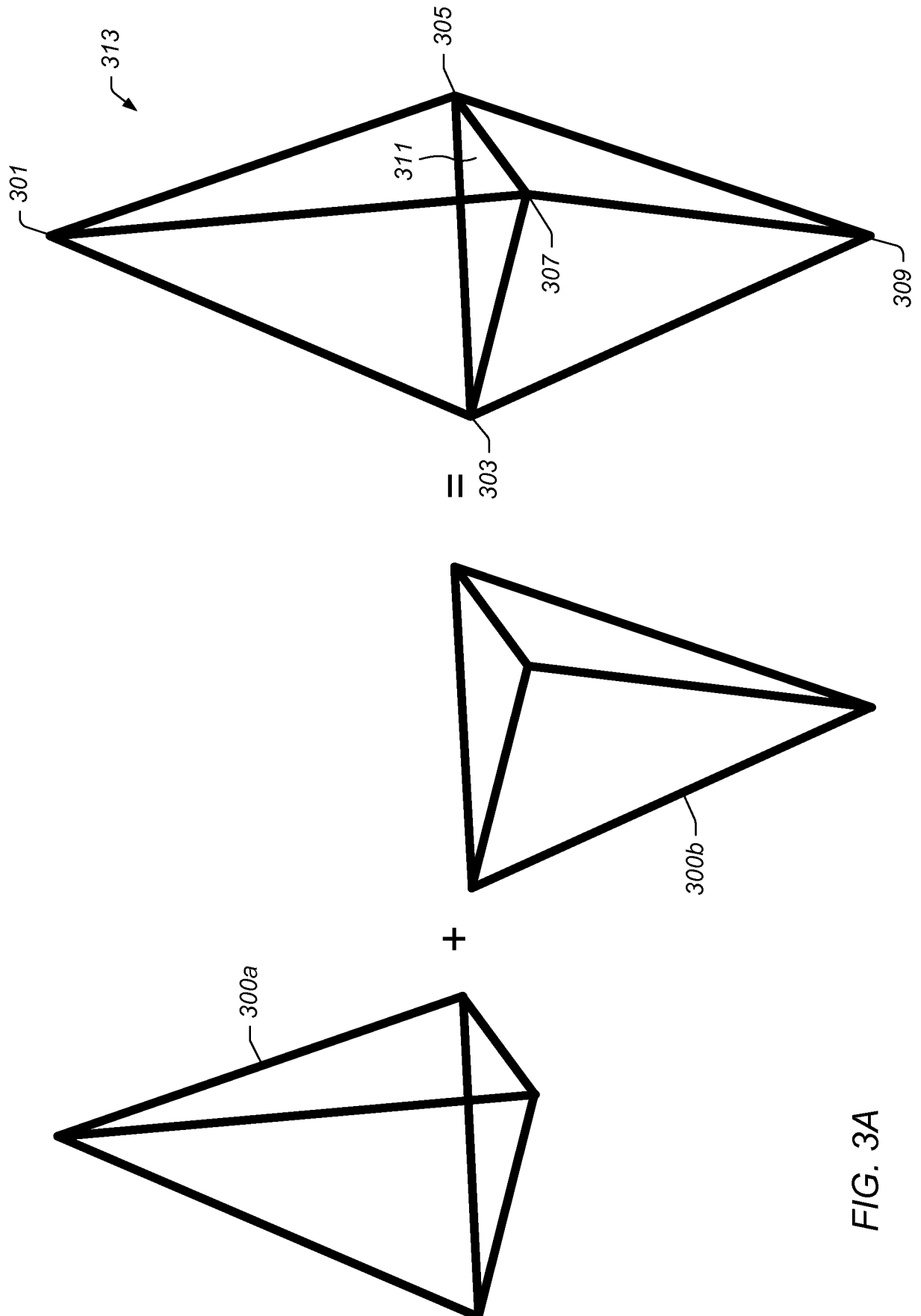
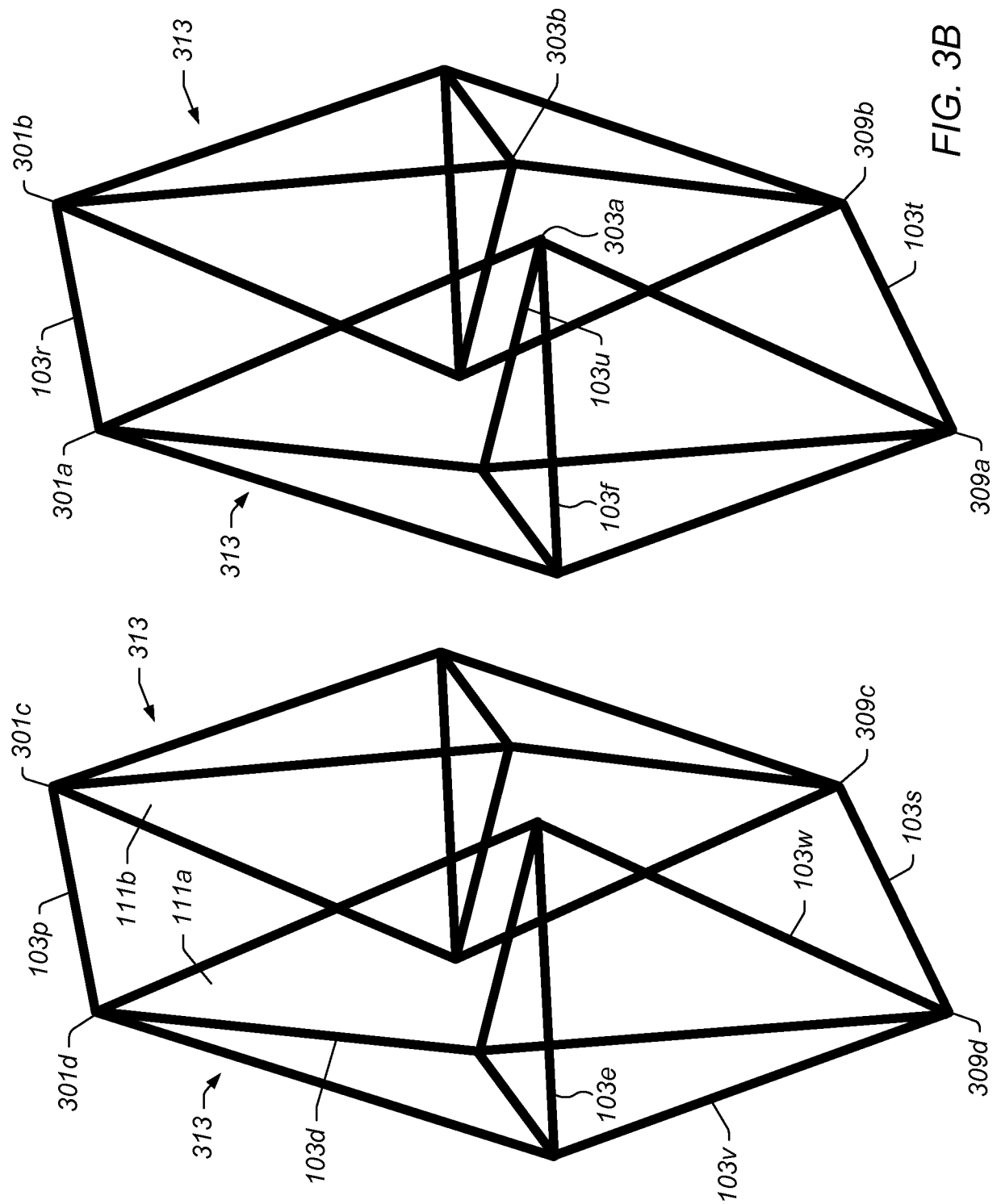
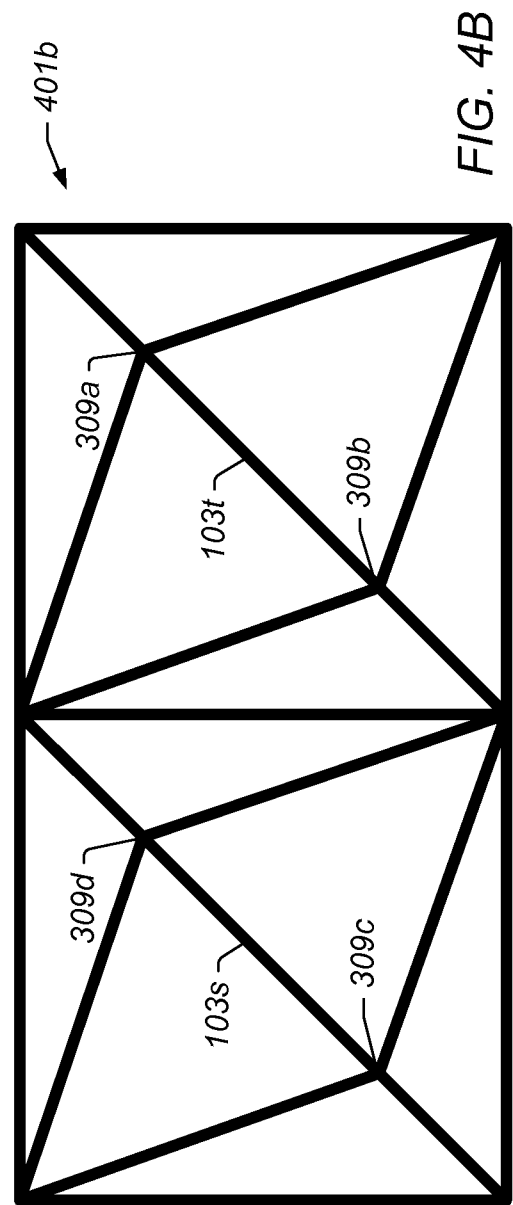
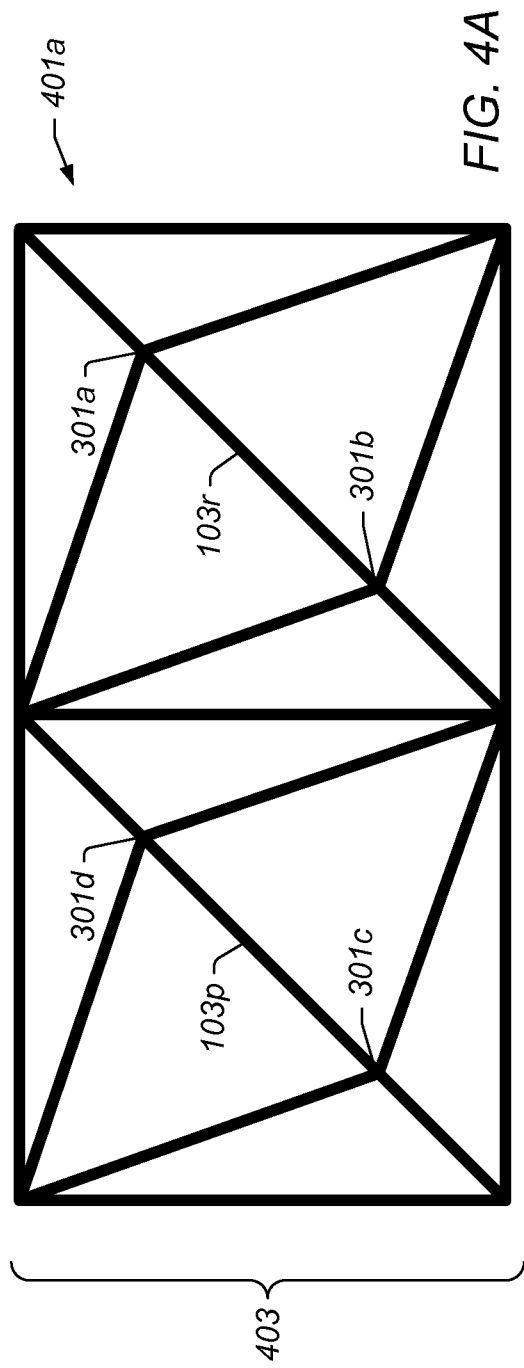


FIG. 2D

6 / 20







9 / 20

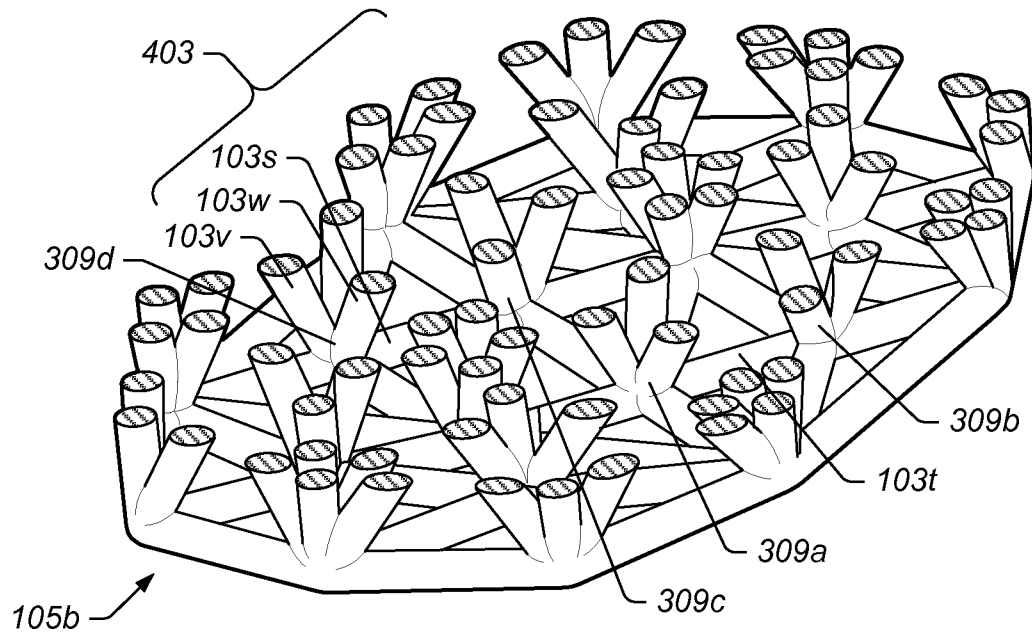


FIG. 5A

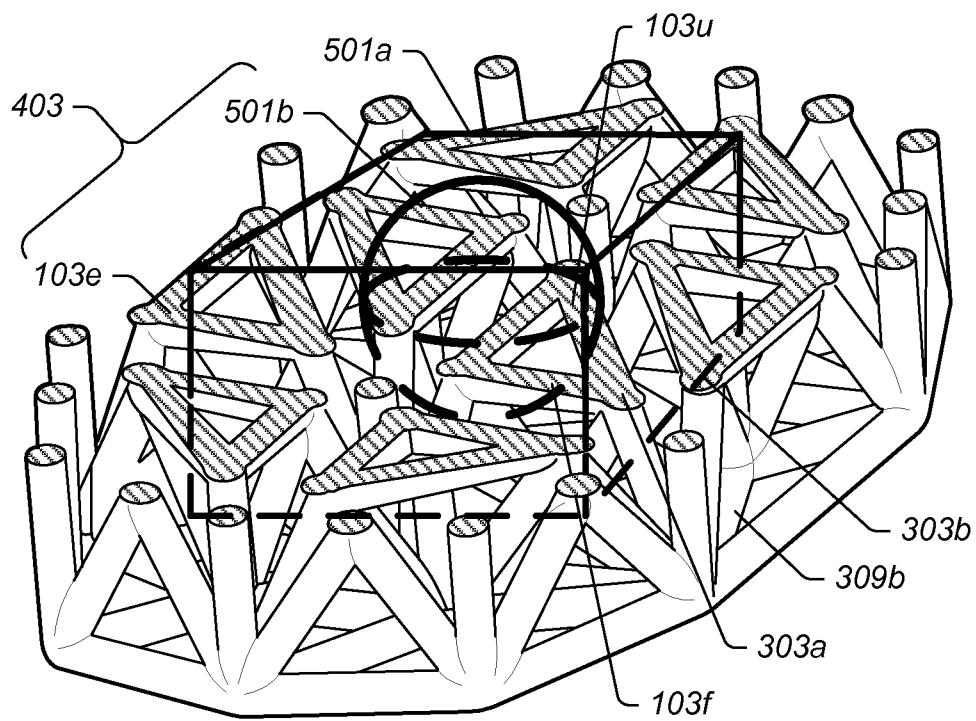


FIG. 5B

10 / 20

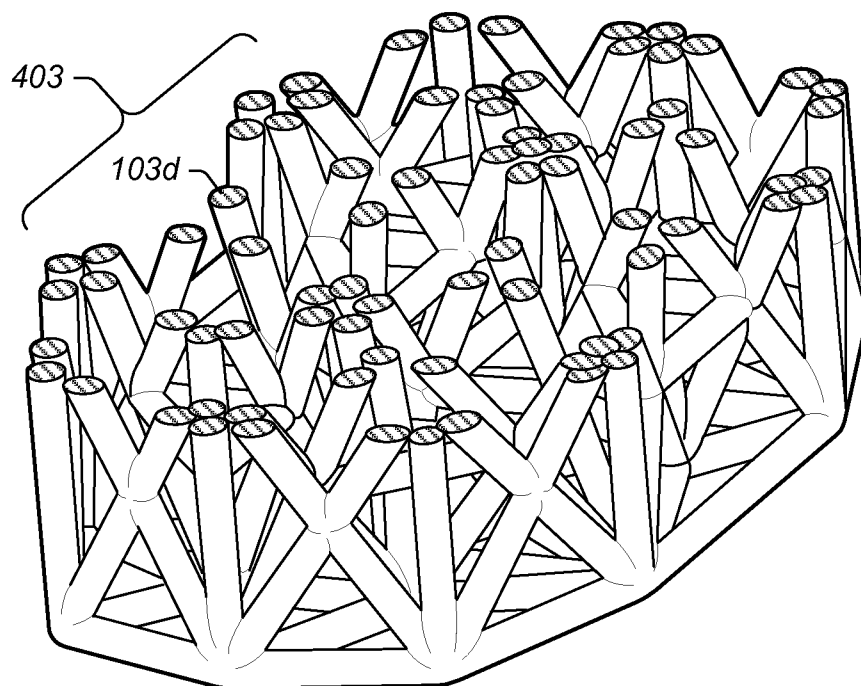


FIG. 5C

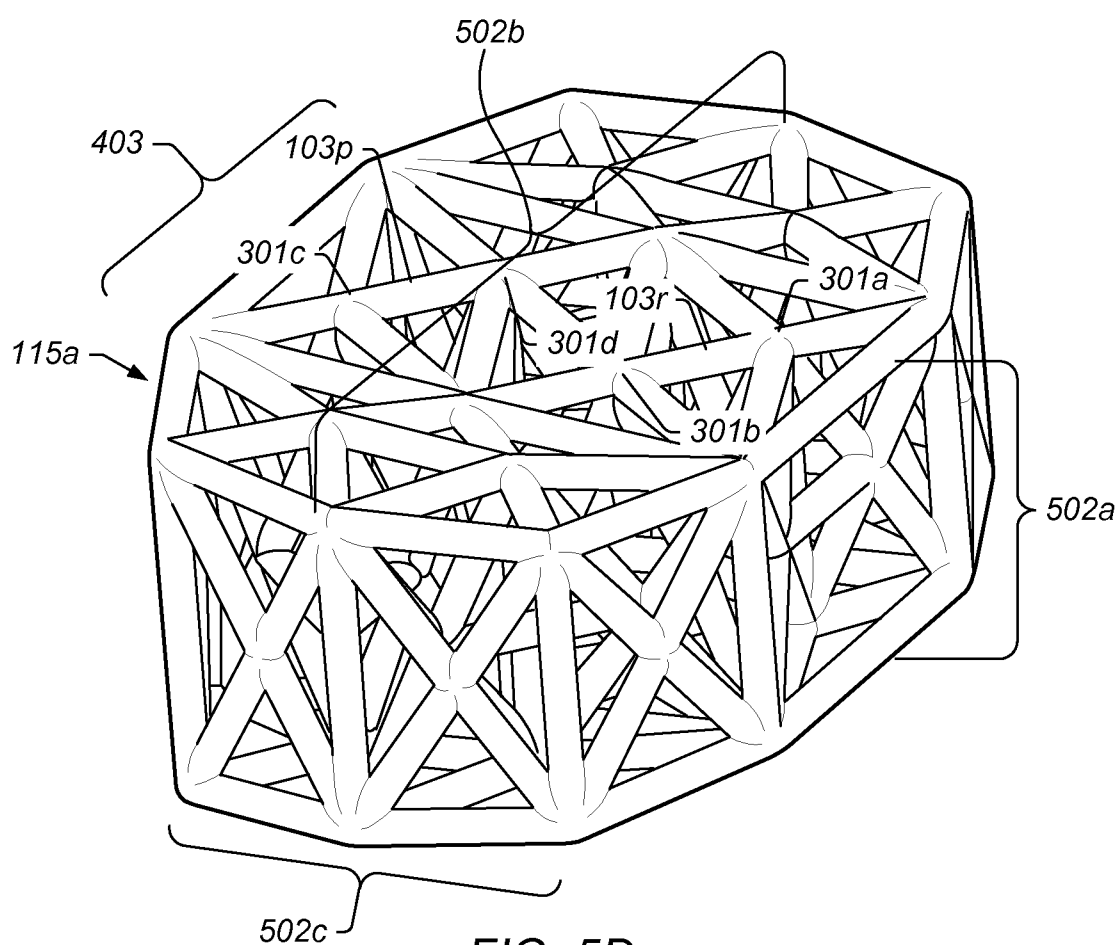


FIG. 5D

11 / 20

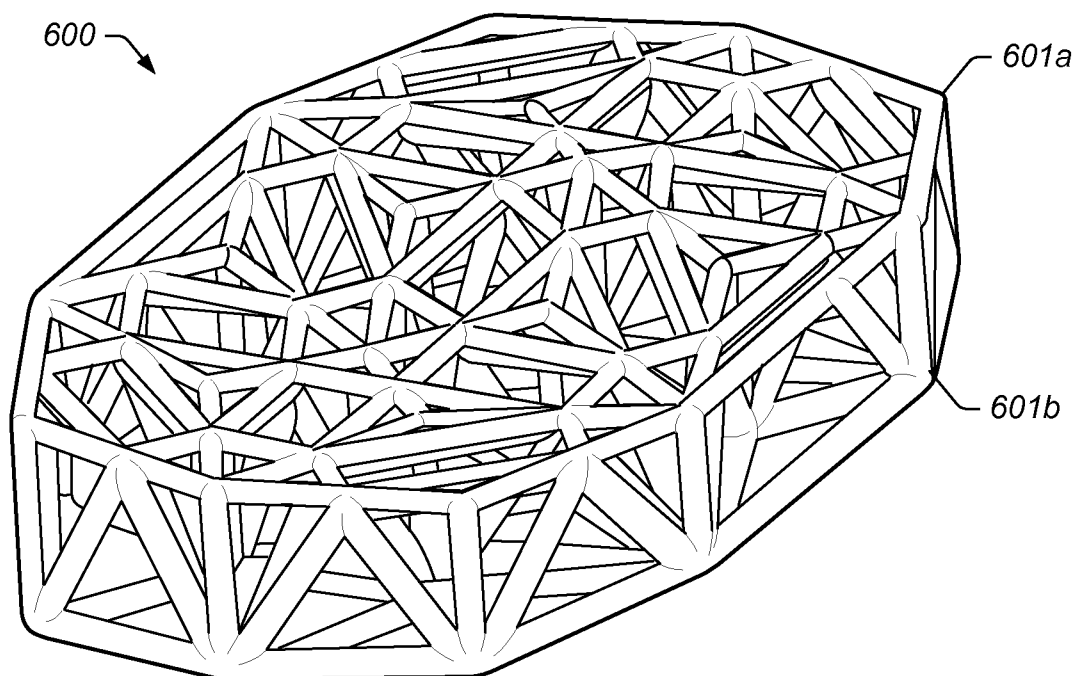


FIG. 6A

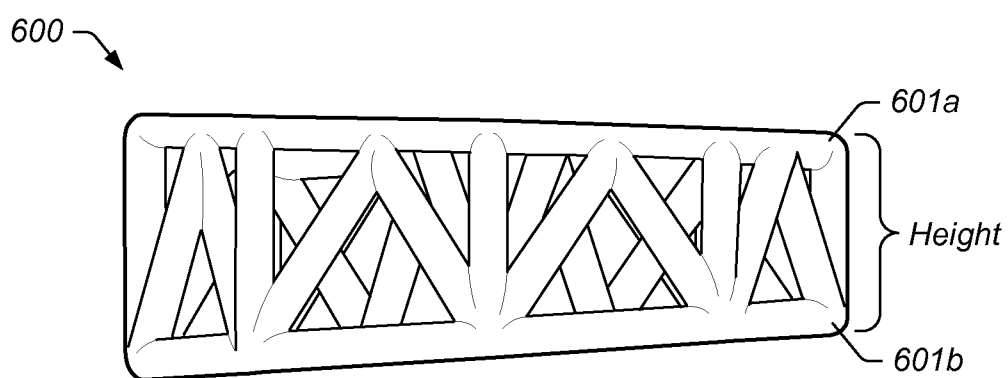


FIG. 6B

12 / 20

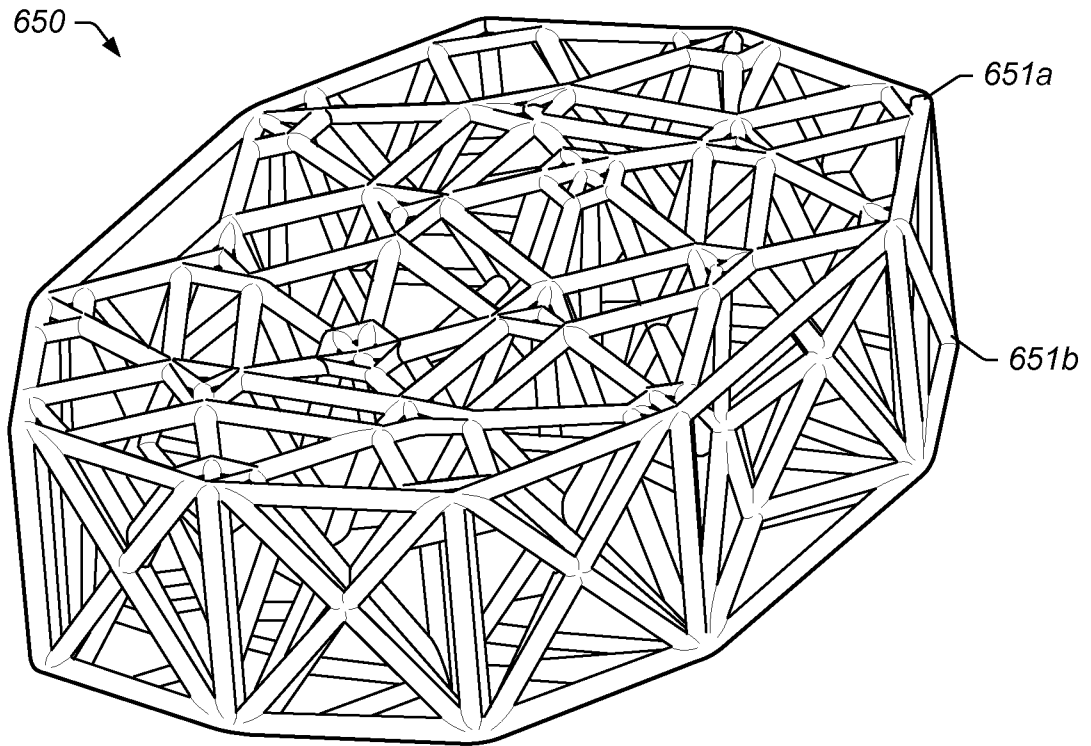


FIG. 6C

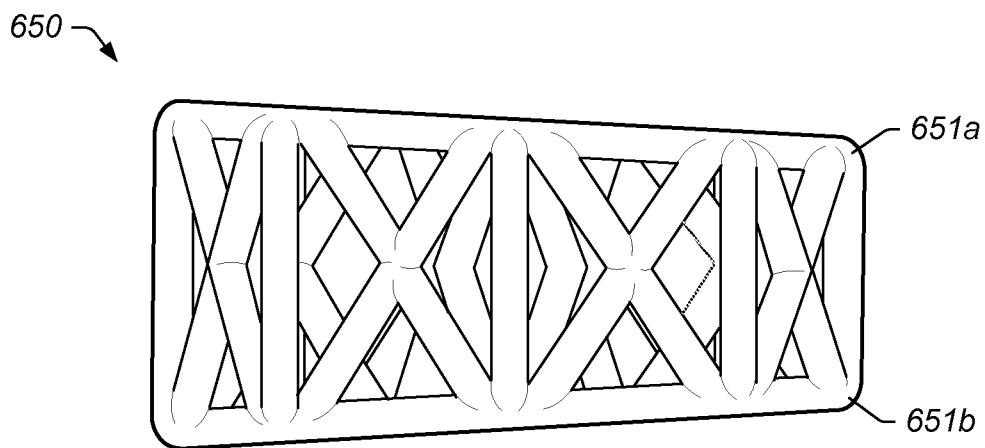


FIG. 6D

13 / 20

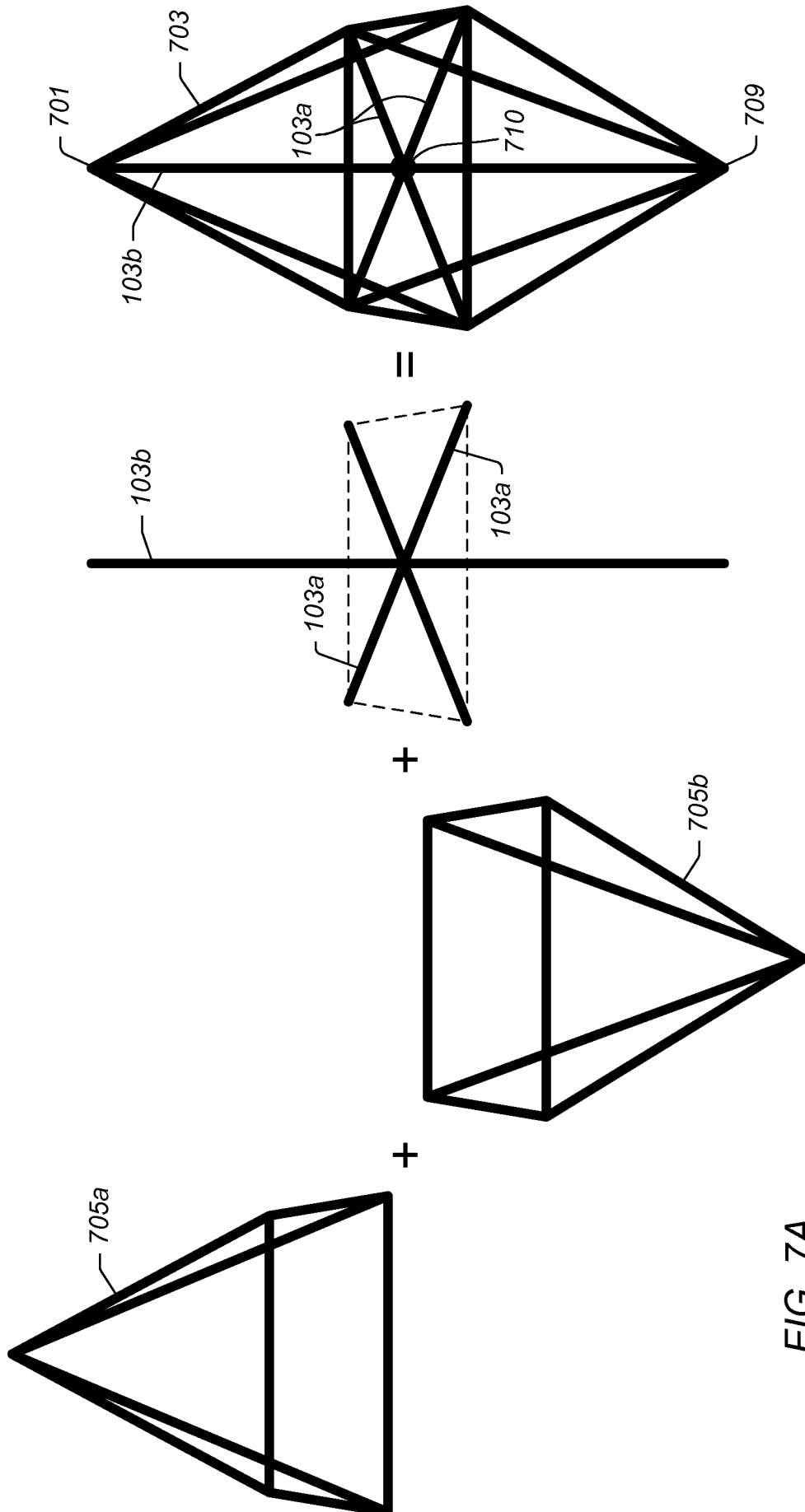


FIG. 7A

14 / 20

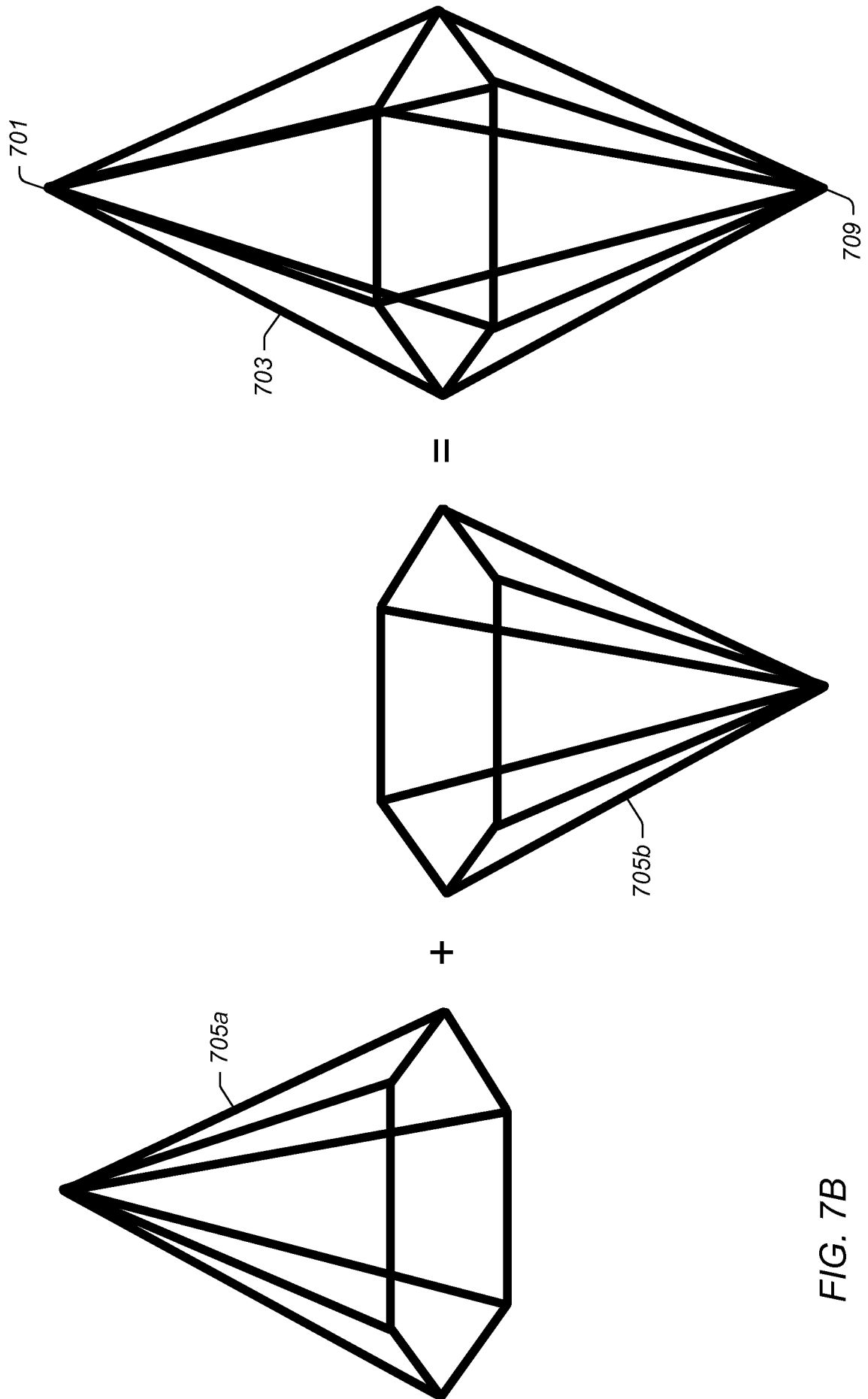


FIG. 7B

15 / 20

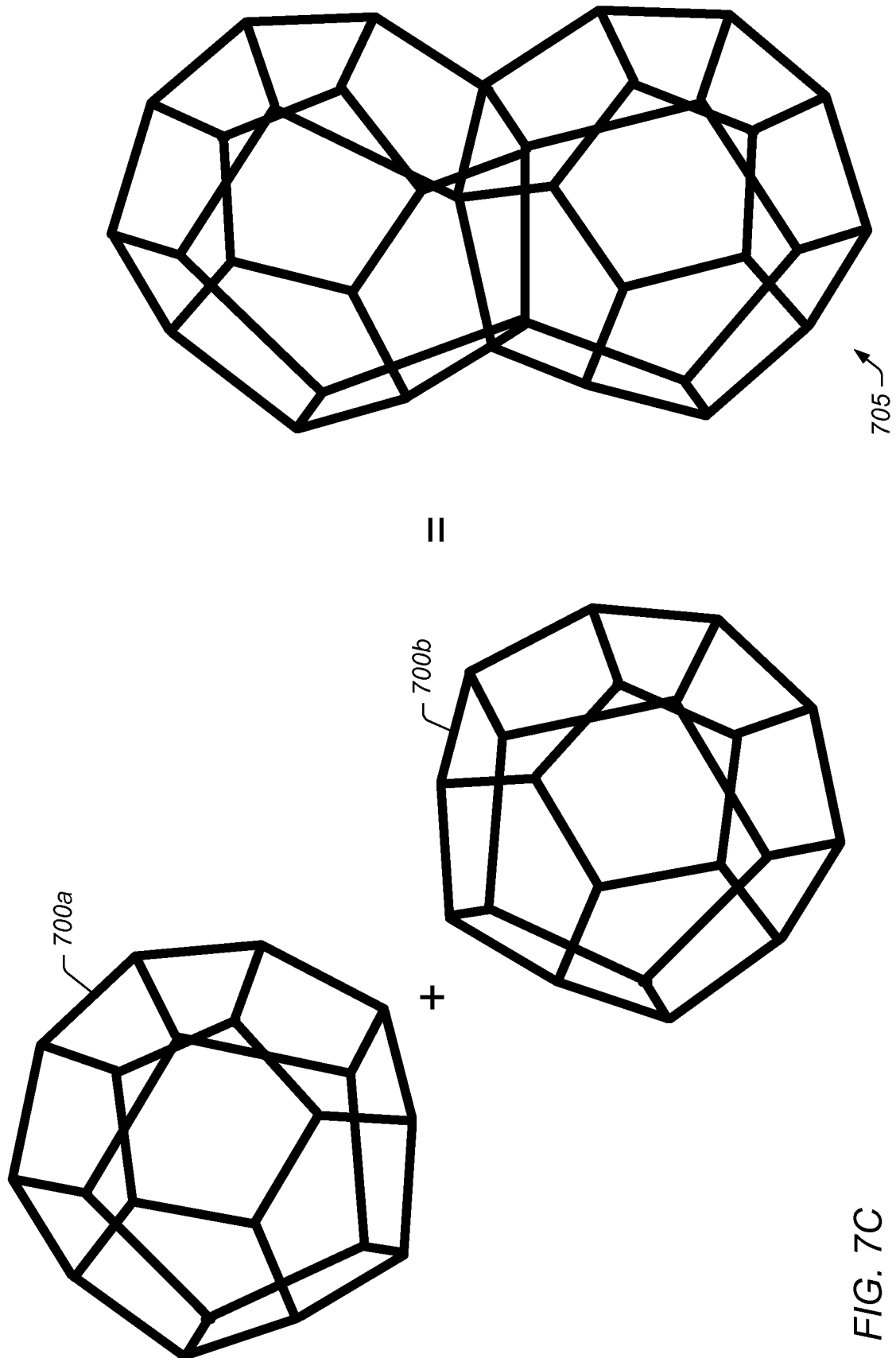


FIG. 7C

16 / 20

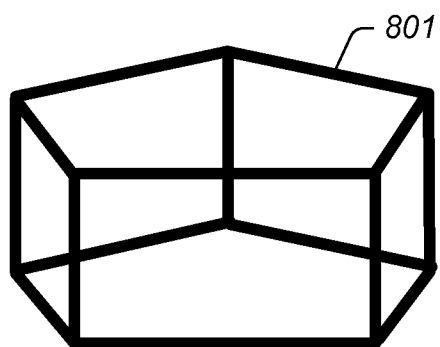


FIG. 8A

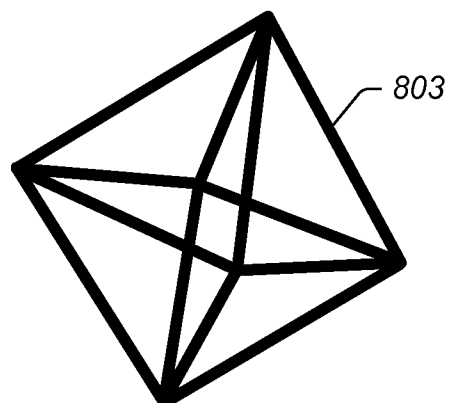


FIG. 8B

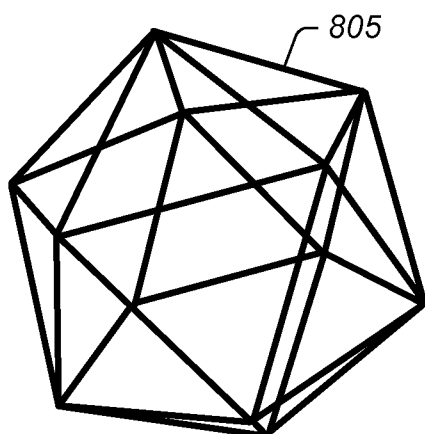


FIG. 8C

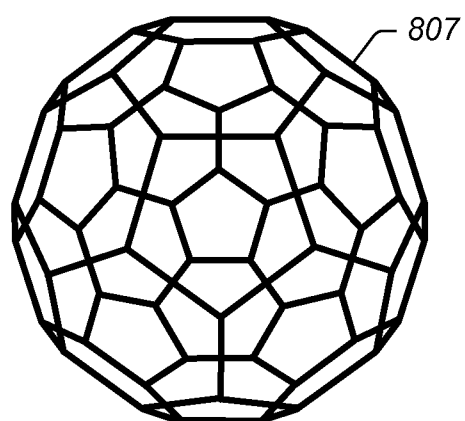


FIG. 8D

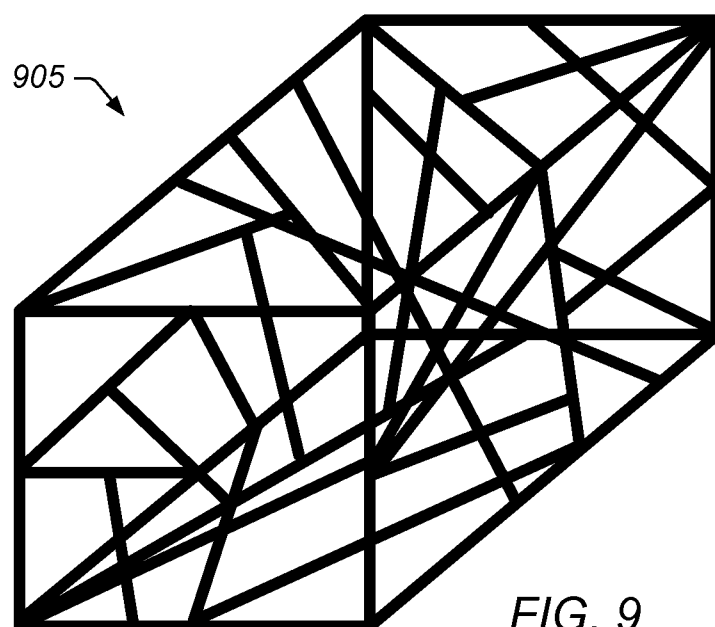


FIG. 9

17 / 20

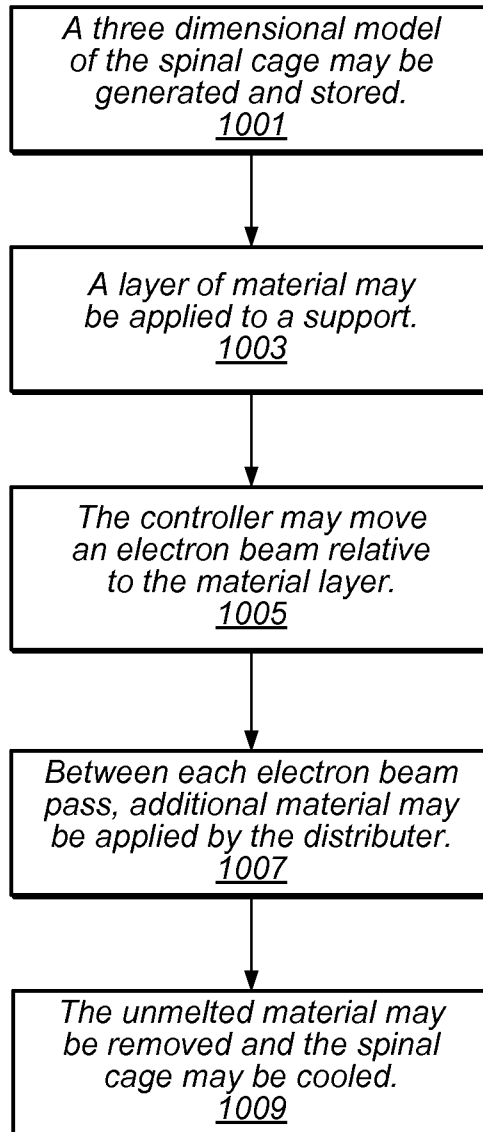


FIG. 10

18 / 20

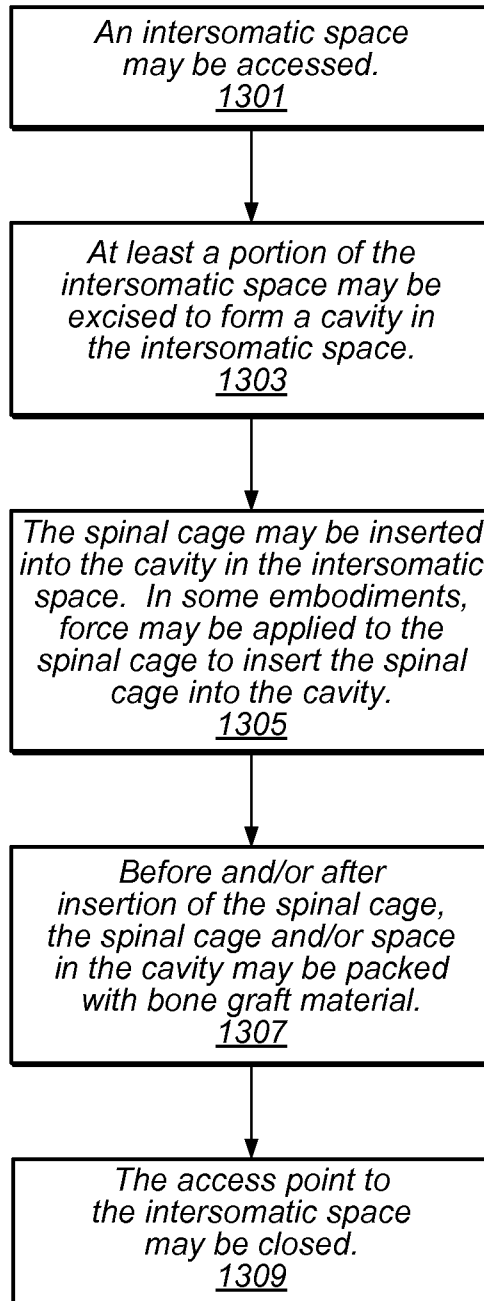
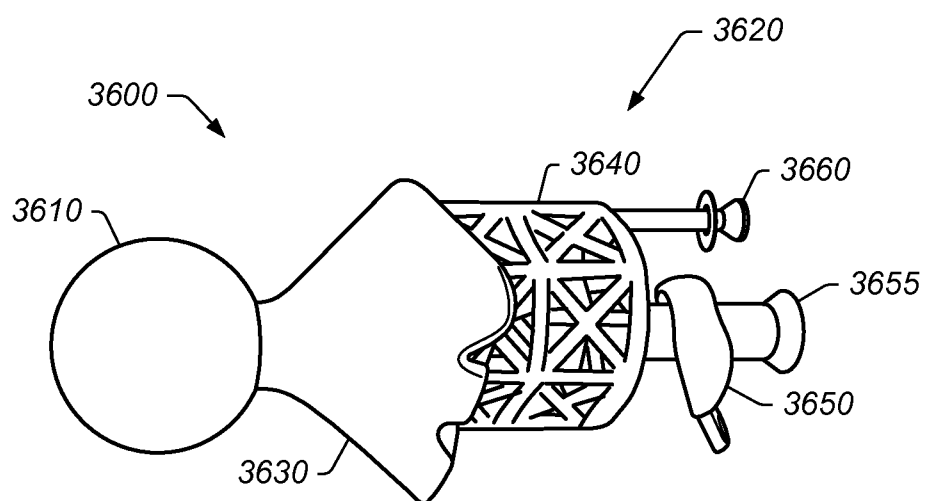
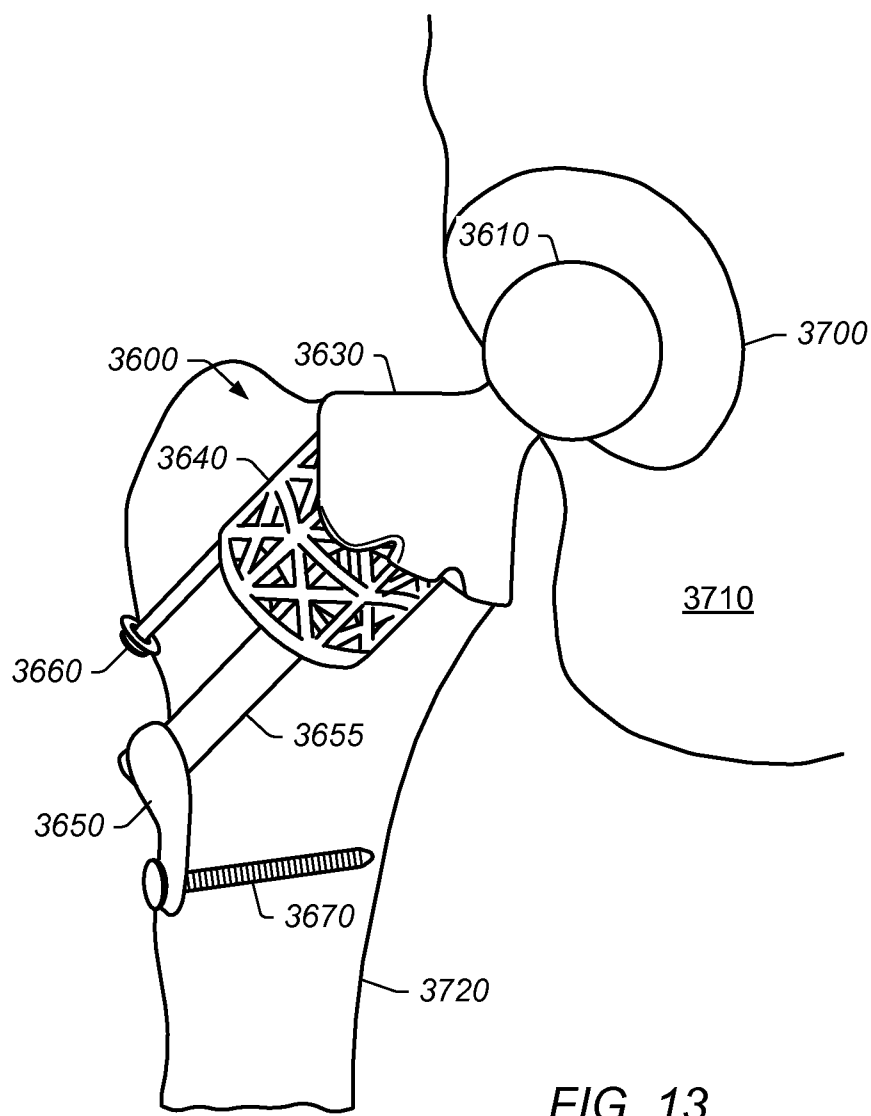


FIG. 11

19 / 20



20 / 20

