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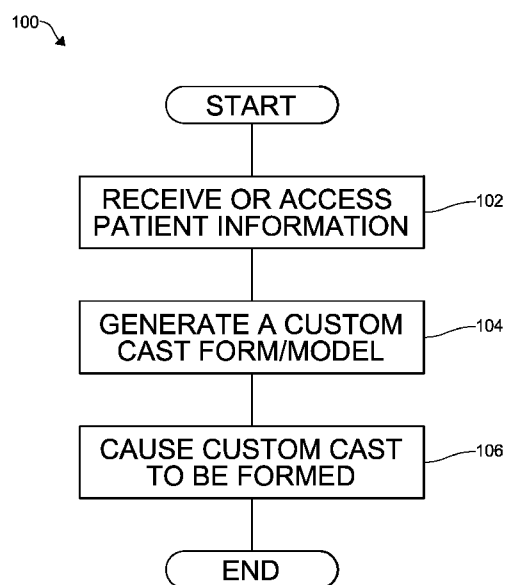


FIG. 1

(57) Abstract: A manufacturing method and articles formed using the same are described. One method includes: receiving spatial information associated with a fractured bone of a patient; generating a custom cast form based at least on the spatial information, wherein the custom cast is form fitted to the patient and/or the fracture bone; and causing a cast to be formed using additive manufacturing based at least on the custom cast form. The cast includes a curvilinear body having a generally lemniscate configuration relative to a longitudinal axis.



CUSTOM CAST AND METHODS FOR MAKING THE SAME

FIELD OF DISCLOSURE

[0001] The present disclosure relates to additive manufacturing methods and systems, and more particularly to additive manufacturing methods and systems that may be used to produce a custom cast.

BACKGROUND OF THE DISCLOSURE

[0002] Three dimensional (3D) printers, commonly referred to as additive manufacturing systems, may use polymeric, composite, or other materials to build a part. Typically, material is heated and liquefied/melted and then drawn through a print head and nozzle of the printer onto the print surface, commonly referred to as the print bed. Some additive manufacturing systems include two or more print heads and nozzles. Once applied to the print bed, the liquefied material solidifies quickly, sealing itself to adjoining printed material. In some examples, the print head and nozzle is moveable in the X and Y directions (i.e., forward and backward, and left and right, respectively) and the print bed is moveable in the Z direction (i.e., up and down) as the material is drawn through the print head and nozzle. In this manner, the print bed and print head(s)/nozzle(s) work together to print in three dimensions.

[0003] Improvements in additive manufacturing processes and application are needed.

BRIEF DESCRIPTION OF THE FIGURES

[0004] In the drawings, which are not necessarily drawn to scale, like numerals may describe similar components in different views. Like numerals having different letter suffixes may represent different instances of similar components. The drawings illustrate generally, by way of example, but not by way of limitation, various embodiments discussed in the present document.

[0005] FIG. 1 is a flow diagram of an example method according to aspects of the present disclosure.

[0006] FIGS. 2A-2C are schematic diagrams of example systems according to aspects of the present disclosure.

[0007] FIG. 3 is a perspective view of an example cast according to aspects of the present disclosure.

[0008] FIG. 4 illustrates perspective view of example casts according to aspects of the present disclosure.

[0009] FIGS. 5A and 5B illustrate an example cast disposed on a wearer's arm according to aspects of the present disclosure.

[0010] FIG. 6 illustrates an example cast including a flex point according to aspects of the present disclosure.

[0011] FIG. 7 illustrates an example cast including a coupling element having elastic bands according to aspects of the present disclosure.

[0012] FIG. 8 illustrates an example cast including a vein feature according to aspects of the present disclosure.

[0013] FIG. 9 illustrates an example cast including a needle element according to aspects of the present disclosure.

[0014] FIG. 10 illustrates an example cast including a coupling element having an aperture and a protrusion configured to be disposed in the aperture according to aspects of the present disclosure.

[0015] FIG. 11 illustrates an example cast including an openable hatch according to aspects of the present disclosure.

[0016] FIG. 12 illustrates an example cast having a transparent or translucent body according to aspects of the present disclosure.

SUMMARY

[0017] Aspects of the disclosure relate to an additive manufacturing method for manufacturing a printed part. In certain aspects the method includes: receiving spatial information associated with a fractured bone of a patient; generating a custom cast form based at least on the spatial information, wherein the custom cast is form fitted to the patient and/or the fracture bone; and causing a cast to be formed using additive manufacturing based at least on the custom cast form. The cast includes a curvilinear body having a generally lemniscate configuration relative to a longitudinal axis. However, other shapes and sizes may be formed to suit a particular wearer (e.g., patient). Since a custom cast form may be generated based on information (e.g.,

spatial information) from various patients, any number of features and custom designs may be used.

DETAILED DESCRIPTION

[0018] Aspects of the disclosure will now be described in detail with reference to the figures, wherein like reference numerals designate identical or corresponding parts throughout the several views, unless specified otherwise.

[0019] Aspects described herein may relate to a method 100 for manufacturing a printed part, such as a custom cast. As illustrated in FIG. 1, in one aspect the method 100 includes receiving or accessing patient information, at step 102. For example, patient information may include spatial information associated with a fractured, or broken, bone of a patient. Such spatial information may be accessed or received based on an imaging technique such as X-ray, magnetic resonance imaging (MRI), optical scanning, and spatial modelling. Other techniques may be used. Spatial information may include dimensions and measurements specific to a given patient.

[0020] At step 104, a custom cast form or model may be generated. As an example, the custom cast form may be based at least on the patient information (e.g., spatial information) accessed or received at step 102. In other words, the cast may be form fitted to or for a given patient for example. The generating the custom cast form or model may include stress analysis, the inclusion or exclusion of custom features based on profiles for the patient and healthcare provider, and/or custom options for aesthetics for functional aspects of the cast.

[0021] At step 106, a cast may be caused to be formed. As an example, the cast may be formed using additive manufacturing based at least on the custom cast form or model. As such, the custom cast model may be digitized and transmitted to a controller for an additive manufacturing device or system. Various additive manufacturing techniques may be used such as fused deposition modeling (FDM) additive manufacturing, selective laser sintering (SLS), stereolithography (SLA), inkjet, etc.

[0022] Various manufacturing methods may be used to form the printed part, such as an additive manufacturing system. An example additive manufacturing system 200 is described in more detail below, but as shown in FIG. 2A it generally

includes a print bed 210 onto which a printed part 10 is formed and a print head/nozzle system 220 that provides the material onto the print bed 210 that forms the printed part 10. The print head/nozzle system 220 includes at least one print head and nozzle 230; as illustrated in FIG. 2A the print head/nozzle system includes two print heads and nozzles 230, 240. The print head/nozzle system 220 is configured to apply one or more materials onto the print bed 210, for example, a first material 250 and a second material 260, according to print location instructions such as those based on a custom cast model. Print instructions (e.g., 3d print model data) such as print location instructions and/or print direction instructions may be routed to the controller 270, and the controller 270 operates a physical control system 280 that moves the print head/nozzle system 220 relative to the print bed 210. In this manner, the print bed 210, print head/nozzle system 220, controller 270 and physical control system 280 operate to form the printed part 10 from the materials 250, 260.

[0023] Individual aspects of the additive manufacturing method 100 will now be described in further detail. It will be recognized that the acts in the method can be performed using a finite element analysis or other system that include, for example, a computer system integrated into an additive manufacturing system 200 or separate from the additive manufacturing system 200.

[0024] In one aspect, the manufacturing method includes an act of receiving print schematics for the part to be printed. For instance, the act can include receiving information from a patient, healthcare provider, or other user that includes patient information, schematics, diagrams, specifications or other data that would allow the additive manufacturing system 200 to form the printed part 10. Print schematics may include standard information that is known in the art, and in some aspects are provided as a 3D computer-aided design (CAD) stereolithography (STL) file format or two-dimensional (2D) CAD file which is converted into an STL file format.

[0025] Based on at least the print schematics, a finite element analysis may be performed on the part to be printed under a load. Generally, finite element analysis involves predicting how a part reacts to real-world forces, heat, vibration, fluid flow or other physical aspects. Finite element analysis can be used to evaluate whether a component will break, wear out, or perform in the manner in which it was designed. Further, finite element analyses are typically used to determine the structural performance of the component. The finite element analysis is performed by meshing

the component (i.e., dividing it into elements), assigning materials to each of the elements, applying boundary conditions to the component, applying the load(s), and applying the finite element analysis using a software program, such as but not limited to Abaqus™ and Ansys™.

[0026]

[0027] In another aspect, the print head/nozzle system includes one print head and nozzle 285, as shown in FIG. 2B. The print head and nozzle 285 includes at least two hoppers 290, 292 into which the materials can be preloaded. A switch 201 operates to control which material exits the print head and nozzle 285 and is applied onto the printed part 10. In a further aspect, as shown in FIG. 2C, the print head/nozzle system 220 includes one print head and nozzle 285, but instead of having both a first material 250 and a second material 260 preloaded therein, the print head/nozzle system 220 includes a base material 262 and a reservoir 202 of a material, such as glass or carbon fibers, that may be compounded with the base material 260 within the print head 285 to form the composite material (tensile material) as demanded by the print head/nozzle system 220.

[0028] Aspects of the additive manufacturing method 100 (FIG. 1) described herein can be incorporated into applications other than those described above. In some aspects, methods described herein can be used to determine a direction of printing in fused filament fabrication (e.g., fused deposition modeling) processes, such as the X-TECH™ process used by Inxide AB. In such processes, a pre-form of continuous fibers is designed and produced, which is then over-molded (e.g., injection molded) using traditional injection processes. The pre-form reinforces the injection molded part. The additive manufacturing method 100 described herein could be used to identify regions in the molded part that are subject to tension and compression. The shape of the pre-form could be tailored based on the identified regions of tension and compression, with the continuous fibers laid only in regions in the molded part that are subject to tension. Further, printing directions for the pre-form could be determined in order to strengthen it.

[0029] In other aspects, the manufacturing method can be used in tailored fiber placement processes such as those used by LayStitch™ Technologies. In current processes utilizing these technologies, topology optimization is used to determine the fiber locations for a part. As an alternative to topology optimization techniques, the

additive manufacturing method 100, 200 according to aspects described herein could be used to identify regions in the part subject to tension and compression, and the fiber locations for the part, and the direction of laying the fiber in the part, can be tailored based on the identified regions of tension and compression.

[0030] Additional manufacturing methods in which aspects of the disclosure could be incorporated include, but are not limited to, selective laser sintering (SLS) methods and stereolithography (SLA) methods.

[0031] For the purposes of the present disclosure, the part to be printed is located in a three-dimensional coordinate system having an X-axis, Y-axis and Z-axis that are all perpendicular to one another. As shown in FIG. 3, the part to be printed 10 includes a longitudinal direction (length) L aligned in the direction of the X-axis, a lateral direction (width A) aligned in the direction of the Y-axis, and a transverse direction (height) T aligned in the direction of the Z-axis. The part to be printed 10 includes a first end 302 and a second end 304 aligned in longitudinal direction L along the X-axis. FIG. 4 illustrates additional purely exemplary examples of shapes, configurations, and structures that may be used for the custom cast.

[0032] As an illustrative example, FIGS. 5A and 5B illustrate a custom cast 502 that has a curvilinear body and a generally lemniscate configuration relative to a longitudinal axis. Lemniscate may refer to a characteristic shape having two loop regions that meet at a central point. The custom cast body may be formed from various materials having various cross-sectional shapes including a ribbon shaped body that is formed to wrap around particular portions of the patient, while leaving portions of the patient's body uncovered by the cast.

[0033] FIG. 6 illustrates an elastic element 604 formed in the body of the custom cast 602, the elastic element configured to facilitate a localized flex point (elastic element 604). As an example, the elastic element may include a series of notched flanges, which cooperate to allow flexure of a portion of the body of the cast 602.

[0034] FIG. 7 illustrates coupling feature 706 disposed to selectively couple two portions 708, 710 of the custom cast 702 to facilitate a dynamic internal volume of the cast 702. As shown, the coupling feature 706 may comprise one or more elastic bands 712 disposed to couple two or more protrusions 714 to each other. As an example, each of a pair of protrusions 714 may be disposed adjacent a respective end

of opposing portions 708, 710 of the cast 702. In this way, the elastic bands 712 may be adjusted to control the resistance to expansion of an internal volume of the cast 702.

[0035] FIG. 8 illustrates a vein structure 816 that may be integrated with at least a portion of the custom cast 802. Such veins may be embodied as channels to facilitate delivery of materials such as treatments, for example.

[0036] The cast may include an orifice or recess to facilitate the introduction of a needle through the cast to the patient's skin 903. As an example, the cast 902 may include a microneedle element 918 as such an orifice or recess, as shown in FIG. 9.

[0037] In some examples, the coupling feature may comprise an aperture and a protrusion configured to be inserted in the aperture to adjust a dimension of the cast. In further examples, the coupling feature may comprise a plurality of protrusions elastically and dynamically coupled together. FIG. 10 illustrates a second coupling feature 1020 comprising an aperture 1022 in at least first portion of the cast 1024 and a protrusion 1026 (in at least second portion of the cast 1028). The protrusion 1026 is configured to be inserted in the aperture 1022 to adjust a dimension of the cast 1002. Any number of apertures 1022 and protrusions 1026 may be configured in any manner to control a dimension of the cast.

[0038] In certain aspects, a portion of the cast 1102 may be configured as a hatch 1130 to allow selective access to a patient's skin, as shown in FIG. 11. The hatch 1130 may provide an open/close functionality or mechanism between selective portions of the cast. For example, the hatch may be openable to allow access to a desired portion of a patient's skin. This may allow for monitoring the progression of wound healing.

[0039] FIG. 12 (as well as FIG. 9) illustrates that at least a portion of the cast 1202 may be formed from a transparent and/or a translucent material.

[0040] In certain examples, the cast may comprise a flexible mechanism, such as a live (or living) hinge. The flexible mechanism may be disposed adjacent an end of the cast relative to the longitudinal axis. The flexible mechanism may be present as a localized thinning or a hinge kind of hook at a portion of the cast. The live hinge may provide a flexible point in the cast.

[0041] The cast may exhibit a hydrophobic property, or anti-fungal, or anti-bacterial property, or a combination thereof. Example 12. The hydrophobic property,

or anti-fungal, or anti-bacterial property may be attributed to the material from which the cast is formed, or to a material forming at least a portion of the cast. In further examples, properties may be attributed to a coating on a surface of the cast.

[0042] It should be appreciated that the present disclosure can include any one up to all of the following examples:

[0043] Example 1. A cast formed by a process comprising: receiving spatial information associated with a fractured bone of a patient; generating a custom cast form based at least on the spatial information, wherein the custom cast is form fitted to the patient and/or the fracture bone; and causing a cast to be formed using additive manufacturing based at least on the custom cast form, wherein the cast comprises a curvilinear body having a generally lemniscate configuration relative to a longitudinal axis.

[0044] Example 2. A cast formed by a process consisting essentially of: receiving spatial information associated with a fractured bone of a patient; generating a custom cast form based at least on the spatial information, wherein the custom cast is form fitted to the patient and/or the fracture bone; and causing a cast to be formed using additive manufacturing based at least on the custom cast form, wherein the cast comprises a curvilinear body having a generally lemniscate configuration relative to a longitudinal axis.

[0045] Example 3. A cast formed by a process consisting of: receiving spatial information associated with a fractured bone of a patient; generating a custom cast form based at least on the spatial information, wherein the custom cast is form fitted to the patient and/or the fracture bone; and causing a cast to be formed using additive manufacturing based at least on the custom cast form, wherein the cast comprises a curvilinear body having a generally lemniscate configuration relative to a longitudinal axis.

[0046] Example 4. The cast of any one of examples 1-3, wherein the cast comprises an elastic element configured to facilitate a localized flex point.

[0047] Example 5. The cast of example any of examples 1-3, wherein the cast comprises a live hinge disposed adjacent an end of the cast relative to the longitudinal axis.

[0048] Example 6. The cast of any one of examples 1-3, wherein the cast comprises a coupling feature disposed to selectively couple two portions of the cast to facilitate a dynamic internal volume of the cast.

[0049] Example 7. The cast of any one of examples 1-3, wherein the cast comprises a coupling feature disposed adjacent an end of the cast relative to the longitudinal axis.

[0050] Example 8. The cast of any one of examples 1-3, wherein the cast comprises a live hinge disposed adjacent a first end of the cast relative to the longitudinal axis and a coupling feature disposed adjacent a second end of the cast opposite the first end.

[0051] Example 9. The cast of any one of examples 7-8, wherein the coupling feature comprises an elastic element configured to facilitate expansion and contraction of the cast relative to a wearer.

[0052] Example 10. The cast of any one of examples 7-8, wherein the coupling feature comprises an aperture and a protrusion configured to be inserted in the aperture to adjust a dimension of the cast.

[0053] Example 11. The cast of any one of examples 1-10, wherein the cast exhibits a hydrophobic, or anti-fungal, or anti-bacterial property, or a combination thereof.

[0054] Example 12. The cast of example 11, wherein the hydrophobic property is facilitated by a material forming at least a portion of the cast or a coating on the cast, or both.

[0055] Example 13. The cast of any one of examples 1-12, wherein the cast comprises a microneedle element disposed in the body.

[0056] Example 14. The cast of any one of examples 1-12, wherein the cast comprises a recess and a microneedle path disposed in the recess.

[0057] Example 15. The cast of any one of examples 1-14, wherein the fractured bone is a compound fracture and the custom cast form is customized for the compound fracture.

[0058] Example 16. A cast comprising a curvilinear body having a generally lemniscate shape relative to a longitudinal axis, wherein the body is custom formed based on a particular wearer and a particular fracture.

[0059] Example 17. A cast consisting essentially of a curvilinear body having a generally lemniscate shape relative to a longitudinal axis, wherein the body is custom formed based on a particular wearer and a particular fracture.

[0060] Example 18. A cast consisting a curvilinear body having a generally lemniscate shape relative to a longitudinal axis, wherein the body is custom formed based on a particular wearer and a particular fracture.

[0061] Example 19. The cast of any of one examples 16-18, wherein the body comprises an elastic element configured to facilitate a localized flex point.

[0062] Example 20. The cast of any of one examples 16-19, wherein the body comprises a live hinge disposed adjacent an end of the cast relative to the longitudinal axis.

[0063] Example 21. The cast of any of one examples 16-19, further comprising a coupling feature disposed to selectively couple two portions of the cast to facilitate a dynamic internal volume of the cast.

[0064] Example 22. The cast of any of one examples 16-19, further comprising a coupling feature disposed adjacent an end of the cast relative to the longitudinal axis.

[0065] Example 23. The cast of any of one examples 16-19, further comprising a live hinge disposed adjacent a first end of the cast relative to the longitudinal axis and a coupling feature disposed adjacent a second end of the cast opposite the first end.

[0066] Example 24. The cast of any one of examples 21-23, wherein the coupling feature comprises an elastic element configured to facilitate expansion and contraction of the cast relative to a wearer.

[0067] Example 25. The cast of any one of examples 21-23, wherein the coupling feature comprises an aperture and a protrusion configured to be inserted in the aperture to adjust a dimension of the cast.

[0068] Example 26. The cast of any one of examples 16-25, wherein the cast exhibits a hydrophobic or anti-fungal, or anti-bacterial property, or a combination thereof.

[0069] Example 27. The cast of example 26, wherein the hydrophobic property is facilitated by a material forming at least a portion of the cast or a coating on the cast, or both.

- [0070] Example 28. The cast of any one of examples 16-27, further comprising a microneedle element disposed in the body.
- [0071] Example 29. The cast of any one of examples 16-28, further comprising a recess and a microneedle path disposed in the recess.
- [0072] Example 30. The cast of any one of examples 16-29, wherein the fractured bone is a compound fracture and the custom cast form is customized for the compound fracture.
- [0073] Example 31. The cast of any one of examples 16-30, further comprising an openable hatch configured to provide access to skin of the patient.
- [0074] Example 32. The cast of any one of examples 16-31, wherein the cast body is formed from multi materials.
- [0075] Example 33. The cast of any one of examples 16-32, wherein the cast body comprises a bio-compatible material disposed in contact with skin of the patient and a structural or aesthetic material disposed external to the bio-compatible material. Such materials may include, for example only, polycarbonate such as LEXAN HP1, LEXAN HS2, LEXAN HS1; and/or polyetherimide such as ULTEM HU 1000.
- [0076] Example 33. The cast of any one of examples 16-32, wherein the cast body/or part of it is formed from a fiber-reinforced composite material.
- [0077] Example 34. The cast of any one of examples 16-33, wherein the cast body comprises stiffening structures.
- [0078] Example 35. The cast of example 34, wherein the stiffening structures are configured based on a load threshold and a desired stiffness level.
- [0079] Example 36. The cast of any one of examples 16-35, wherein the cast body comprises breathable pores.
- [0080] Example 37. The cast of any one of examples 16-36, further comprising a foam injected adjacent at least a portion of the body.
- [0081] Example 38. The cast of any one of examples 16-37, wherein the body of the cast is sterilized. Such sterilization may be any known sterilization technique including gamma sterilization or steam sterilization/autoclave.
- [0082] Example 39. The cast of any one of examples 16-38, wherein at least a portion of the body of the cast is transparent or translucent.
- [0083] Example 40. The cast of any one of examples 16-39, further comprising a drug release element disposed adjacent the body.

[0084] Example 41. The cast of any one of examples 16-40, wherein one or more protrusions are formed on an interior surface of the body.

[0085] Example 42. The cast of any one of examples 16-41, further comprising a lining material disposed adjacent an interior surface of the body.

[0086] Example 43. The cast of example 42, wherein the lining material comprises a biocompatible material, an elastomeric material, or soft touch material, or a combination thereof. Such materials may include, for example only, silicone rubber and/or thermoplastic elastomers.

[0087] Example 44. The cast of any one of examples 16-43, further comprising a decorative feature disposed on an exterior surface of the body.

[0088] Example 45. The cast of any one of examples 16-44, further comprising one or more hooks integrated with the body.

[0089] Example 46. The cast of any one of examples 16-45, further comprising a thermal channel formed in the body.

[0090] Example 47. A method of making the cast of any one of examples 16-46.

[0091] Example 48. The method of example 47, wherein the cast is formed using additive manufacturing.

[0092] Various customizations may be made on-demand for one or more patients. For example, the cast may include stiffening structures. Stiffening structures may refer to printed features of the cast configured to reduce the overall weight of the cast or to improve the stiffness to weight ratio (features like honeycomb between the walls). Stiffness may be customized based on the load the cast needs to take. The stiffening structures may be configured based on at least a load threshold to achieve a desired stiffness of the cast. The stiffening structures may be configured to provide a pre-defined or pre-determined stiffness to the cast based on the needs of a specific patient or wearer. The load threshold may be dependent upon one or more of the particular patient (or wearer) or particular type of fracture (for example, a compound fracture). Various features may be used to achieve a desired stiffness and may include, but are not limited to, internal ribbing, honeycomb structures, structural foam, continuous fiber reinforcements, and metal reinforcements. The printed structure may be formed with breathable pores to prevent foul smell during prolonged usage of the cast. In an example, the cast may be printed hollow between the walls

and foam is injected between the walls to improve the overall stiffness by creating a sandwich structure. In further examples, the printed material may be translucent which helps in monitoring the wound healing in the case of compound fracture. The cast may include one or more of the foregoing features and/or structural elements.

[0093] In case the wound needs to be medicated frequently, a drug administering features can be printed integral to the cast. These features can hold the drug and release the drug in controlled manner. The drug can be refilled to the cast feature through a one-way valve or through a lid mechanism. Small projections can be printed in the cast to reduce the contact surface with the skin.

[0094] In the cast, at a surface which comes in contact with skin, a biocompatible lining material can be printed or sticker of lining material can be placed to reduce the abrasion of the skin. The lining material can be of elastomeric material or a soft touch material. Soft touch material may refer to a coating or adhesive surface that, when applied, creates a velvet-like texture in that the surface to which it is applied becomes soft to the touch. Soft touch material may also refer to a coating commercially available as Soft Touch™. The skin of the printed cast can have decorative features like patterns, colors or even area for graphics or signature. One or more hooks may be printed integral to the cast in case of traction or belt support or shoulder support is needed.

[0095] Injection molded standard elements are used in conjunction with 3D printed parts to enable quick printing. These standard elements are also act as structural members. Heating or cooling channels can be printed in the cast which can help in wound healing process. The entire printed cast or a portion thereof can be dipped in epoxy or similar sealing materials in case there is a need for airtight surface

[0096] Each of these non-limiting examples can stand on its own, or can be combined in various permutations or combinations with one or more of the other examples.

[0097] The above detailed description includes references to the accompanying drawings, which form a part of the detailed description. The drawings show, by way of illustration, specific embodiments in which the disclosure can be practiced. These embodiments are also referred to herein as “examples.” Such examples can include elements in addition to those shown or described. However, the present inventors also contemplate examples in which only those elements shown or

described are provided. Moreover, the present inventors also contemplate examples using any combination or permutation of those elements shown or described (or one or more aspects thereof), either with respect to a particular example (or one or more aspects thereof), or with respect to other examples (or one or more aspects thereof) shown or described herein.

[0098] In the event of inconsistent usages between this document and any documents so incorporated by reference, the usage in this document controls.

[0099] In this document, the terms “a” or “an” are used, as is common in patent documents, to include one or more than one, independent of any other instances or usages of “at least one” or “one or more.” In this document, the term “or” is used to refer to a nonexclusive or, such that “A or B” includes “A but not B,” “B but not A,” and “A and B,” unless otherwise indicated. In this document, the terms “including” and “in which” are used as the plain-English equivalents of the respective terms “comprising” and “wherein.” Also, in the following claims, the terms “including” and “comprising” are open-ended, that is, a system, device, article, composition, formulation, or process that includes elements in addition to those listed after such a term in a claim are still deemed to fall within the scope of that claim. Moreover, in the following claims, the terms “first,” “second,” and “third,” etc. are used merely as labels, and are not intended to impose numerical requirements on their objects.

[00100] Method examples described herein can be machine or computer-implemented at least in part. Some examples can include a computer-readable medium or machine-readable medium encoded with instructions operable to configure an electronic device to perform methods as described in the above examples. An implementation of such methods can include code, such as microcode, assembly language code, a higher-level language code, or the like. Such code can include computer readable instructions for performing various methods. The code may form portions of computer program products. Further, in an example, the code can be tangibly stored on one or more volatile, non-transitory, or non-volatile tangible computer-readable media, such as during execution or at other times. Examples of these tangible computer-readable media can include, but are not limited to, hard disks, removable magnetic disks, removable optical disks (e.g., compact disks and digital

video disks), magnetic cassettes, memory cards or sticks, random access memories (RAMs), read only memories (ROMs), and the like.

[00101] The above description is intended to be illustrative, and not restrictive. For example, the above-described examples (or one or more aspects thereof) may be used in combination with each other. Other embodiments can be used, such as by one of ordinary skill in the art upon reviewing the above description. The Abstract is provided to comply with 37 C.F.R. §1.72(b), to allow the reader to quickly ascertain the nature of the technical disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. Also, in the above Detailed Description, various features may be grouped together to streamline the disclosure. This should not be interpreted as intending that an unclaimed disclosed feature is essential to any claim. Rather, inventive subject matter may lie in less than all features of a particular disclosed embodiment. Thus, the following claims are hereby incorporated into the Detailed Description as examples or embodiments, with each claim standing on its own as a separate embodiment, and it is contemplated that such embodiments can be combined with each other in various combinations or permutations. The scope of the disclosure should be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled.

CLAIMS

That which is claimed is:

1. A cast formed by a process comprising:
receiving spatial information associated with a fractured bone of a patient;
generating a custom cast form based at least on the spatial information,
wherein the custom cast is form fitted to a patient or wearer or a
fractured bone of the patient or wearer; and
causing the custom cast to be formed using additive manufacturing based at
least on the custom cast form, wherein the cast comprises a curvilinear
body having a generally lemniscate configuration relative to a
longitudinal axis.
2. The cast of claim 1, wherein the custom cast comprises an elastic element
configured to facilitate a localized flex point.
3. The cast of any one of claims 1-2, wherein the custom cast comprises a
coupling feature disposed to selectively couple two portions of the cast to
facilitate a dynamic internal volume of the cast.
4. The cast of claim 3, wherein the coupling feature comprises an aperture and a
protrusion configured to be inserted in the aperture to adjust a dimension of the
cast or a plurality of protrusions elastically and dynamically coupled together,
or a combination thereof.
5. The cast of any one of claims 1-4, wherein the cast exhibits a hydrophobic
property, an anti-fungal property, an anti-bacterial property, or a combination
thereof.
6. The cast of any one of claims 1-5, wherein the cast comprises a microneedle
element disposed in the curvilinear body.

7. A cast comprising a curvilinear body having a generally lemniscate shape relative to a longitudinal axis, wherein the curvilinear body is custom-formed to provide a custom cast form based on a particular wearer and a particular fracture.
8. The cast of claim 7, wherein the curvilinear body comprises stiffening structures.
9. The cast of claim 8, wherein the stiffening structures are configured based on at least a load threshold that is dependent upon the patient or wearer or particular fracture.
10. The cast of any one of claims 7-9, wherein the fractured bone is a compound fracture and the custom cast form is customized for the compound fracture.
11. The cast of any one of claims 7-10, further comprising an openable hatch configured to provide access to skin of the patient or wearer.
12. The cast of any one of claims 7-11, wherein the cast is formed from multiple materials.
13. The cast of any one of claims 7-12, wherein the cast comprises a bio-compatible material disposed in contact with skin of the patient or wearer and a structural or aesthetic material disposed external to the bio-compatible material.
14. The cast of any one of claims 7-13, wherein at least a portion of the cast is formed from a fiber-reinforced composite material.
15. The cast of any one of claims 7-14, further comprising foam disposed adjacent at least a portion of the curvilinear body of the cast.
16. The cast of any one of claims 7-15, wherein the curvilinear body of the cast is sterilized.

17. The cast of any one of claims 7-16, further comprising a lining material disposed adjacent an interior surface of the curvilinear body of the cast.
18. The cast of claim 17, wherein the lining material comprises a biocompatible material, an elastomeric material, a soft touch material, or a combination thereof.
19. The cast of any one of claims 7-18, further comprising a decorative feature disposed on an exterior surface of the curvilinear body of the cast.
20. The cast of any one of claims 7-19, further comprising one or more hooks integrated with the curvilinear body of the cast.

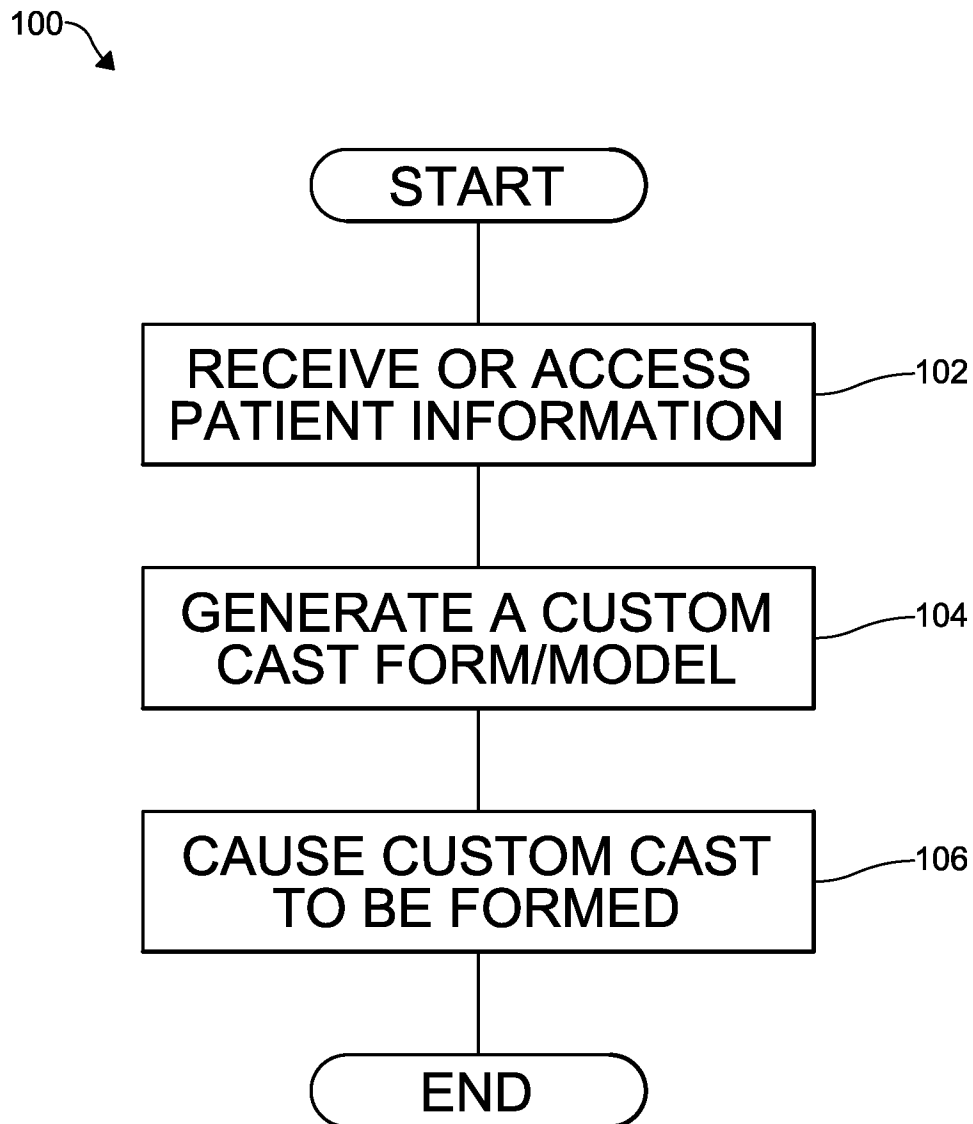


FIG. 1

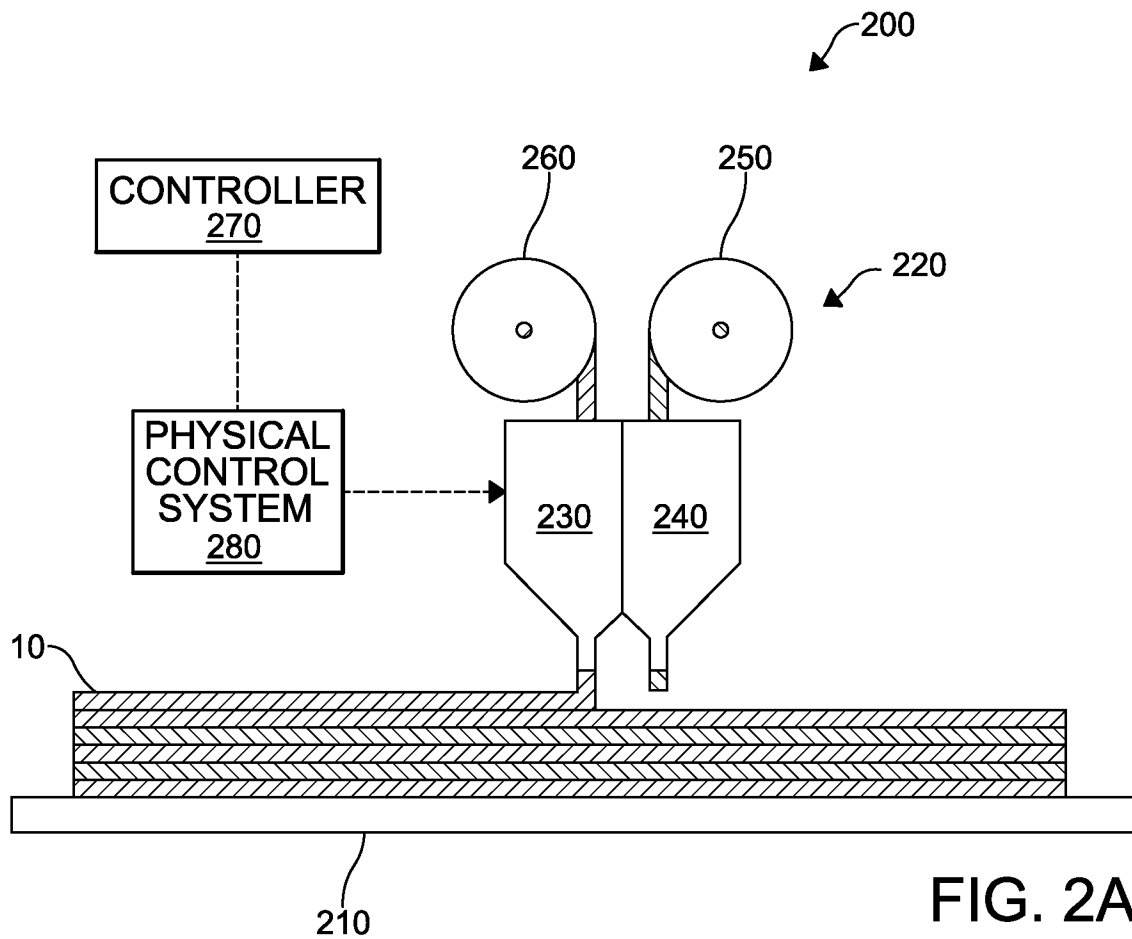


FIG. 2A

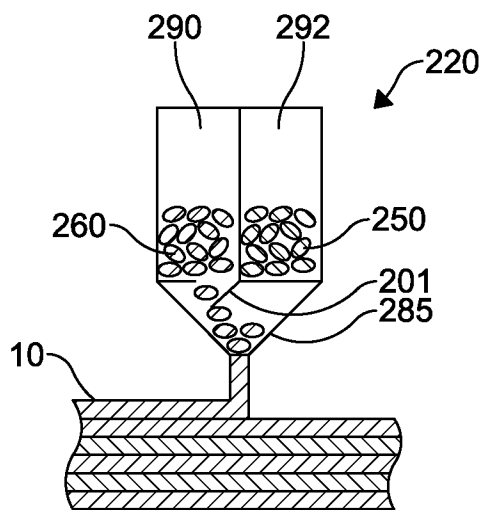


FIG. 2B

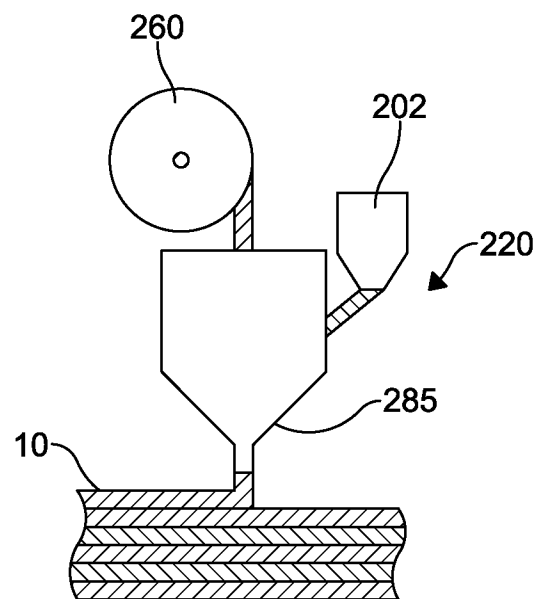
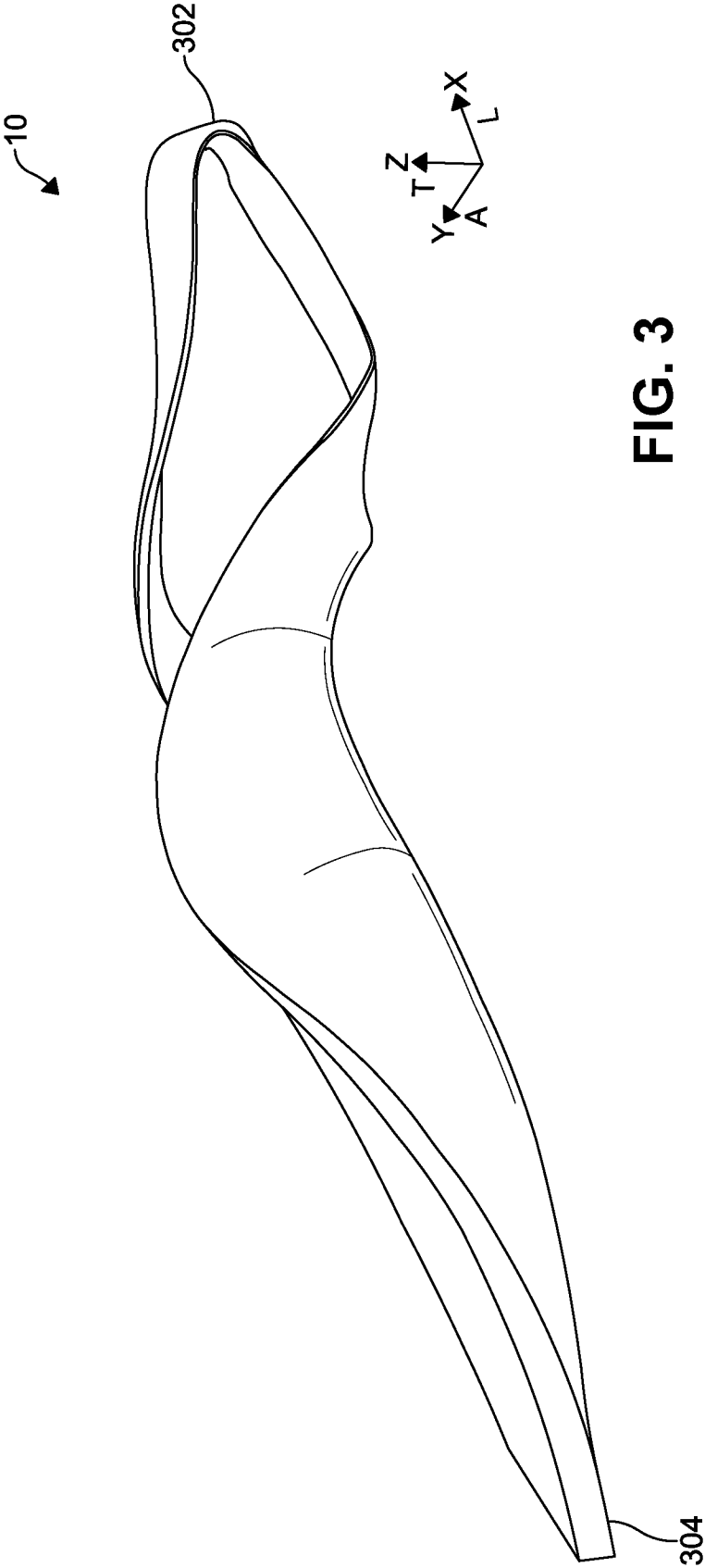


FIG. 2C



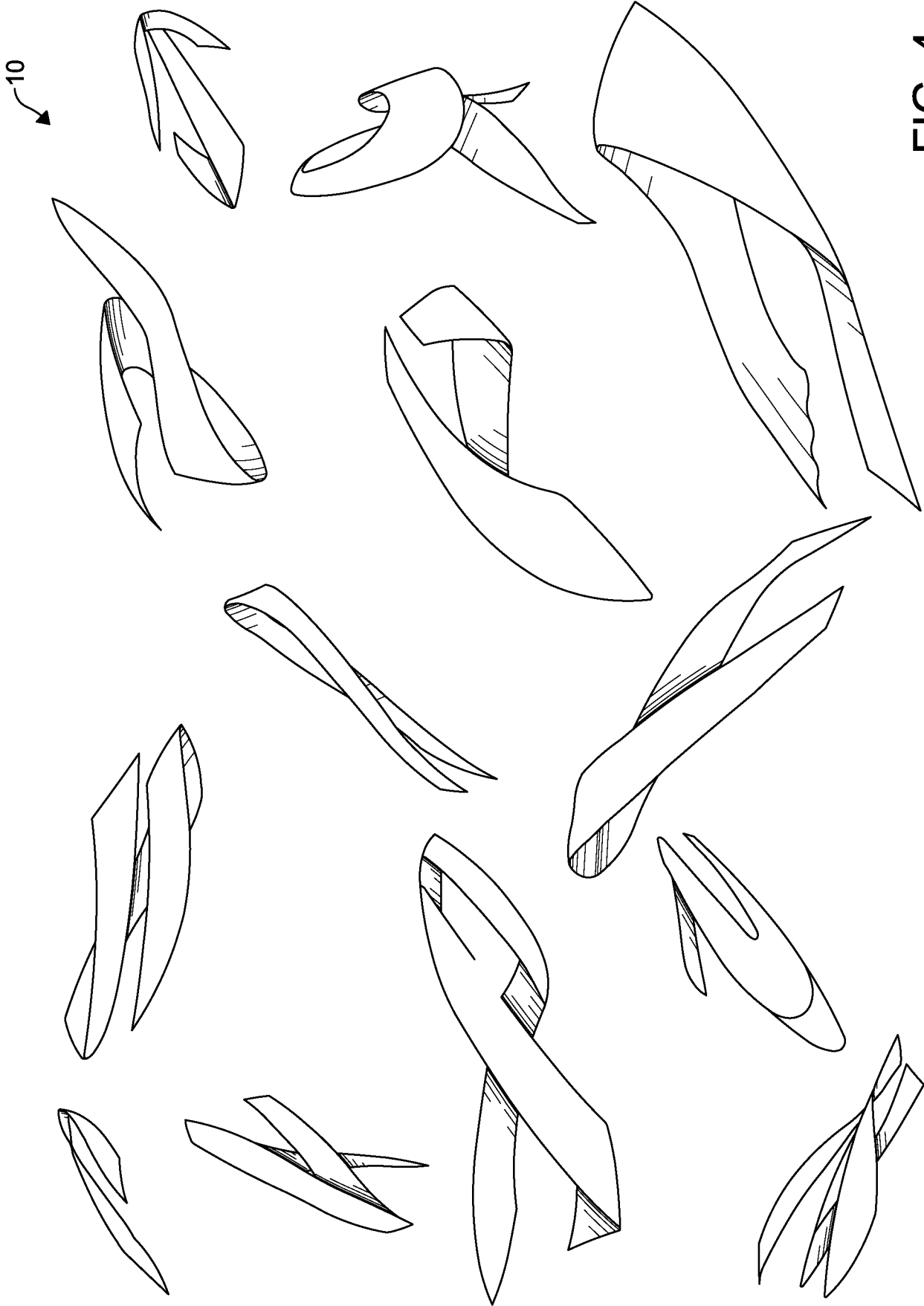


FIG. 4

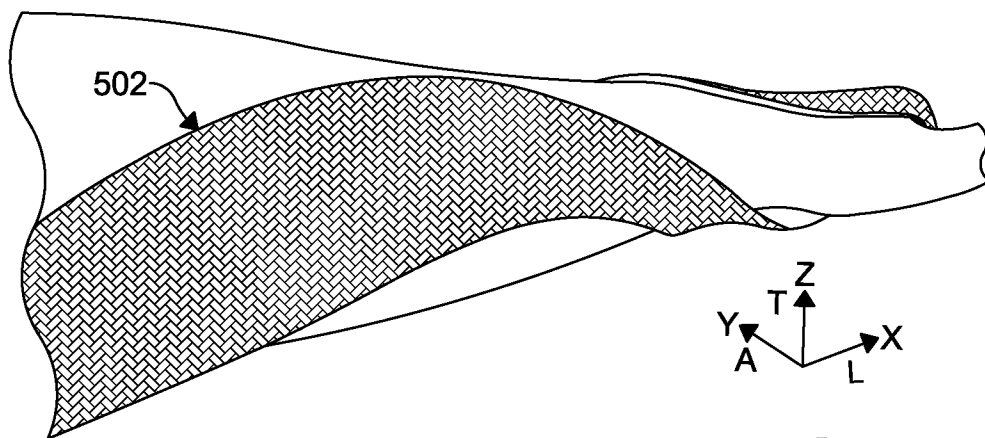


FIG. 5A

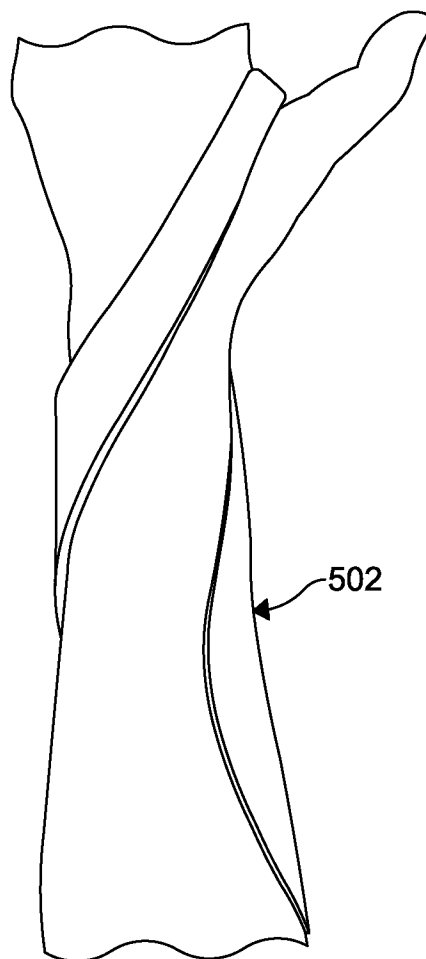
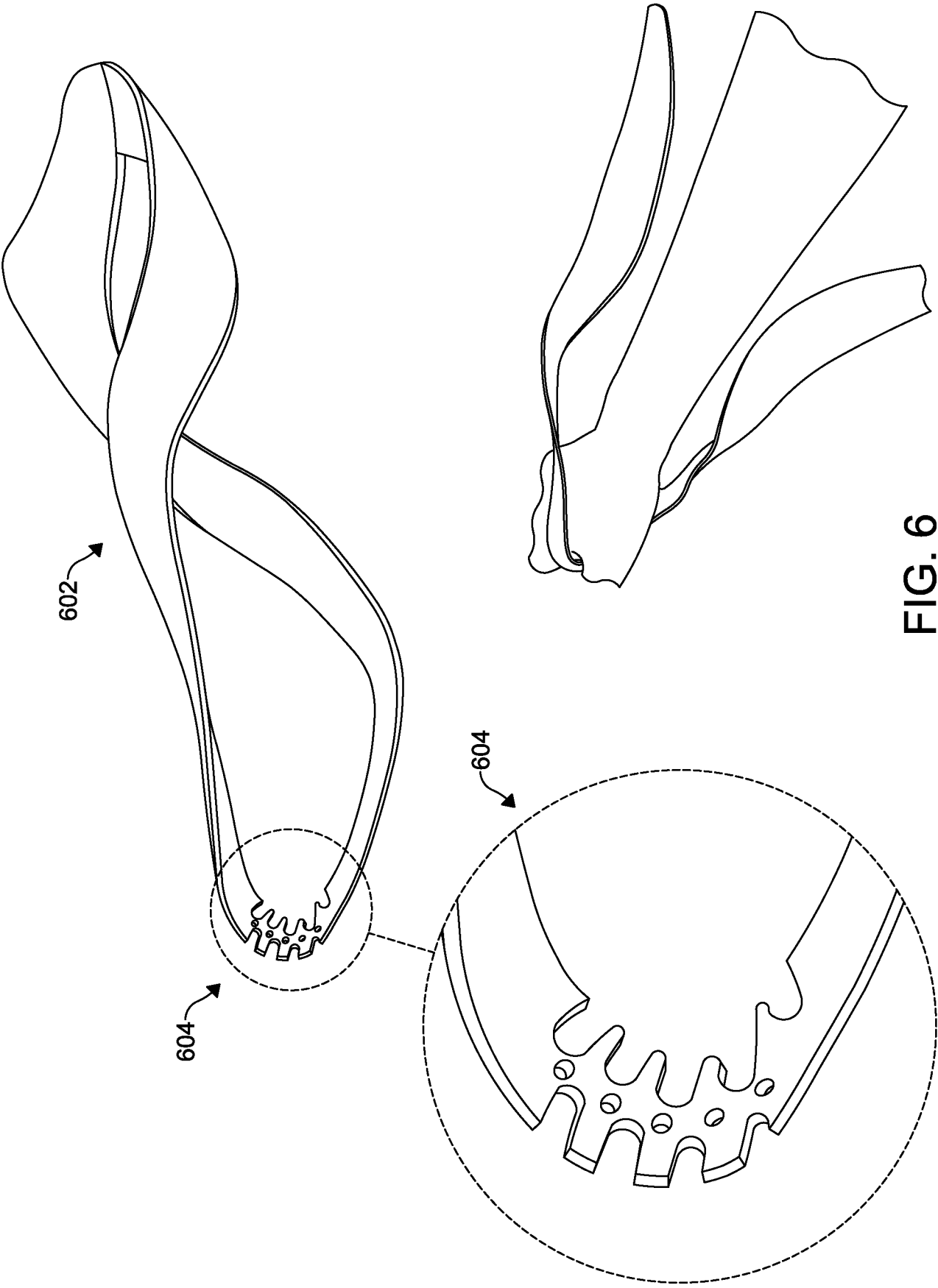


FIG. 5B



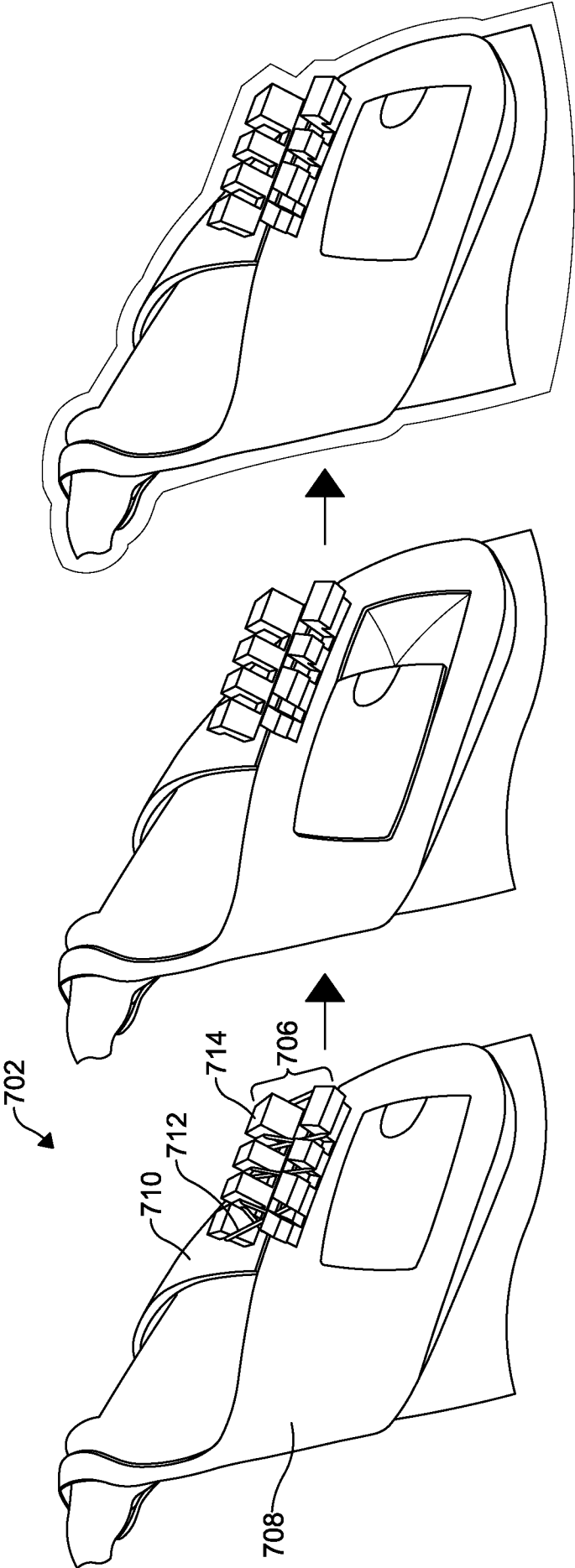


FIG. 7

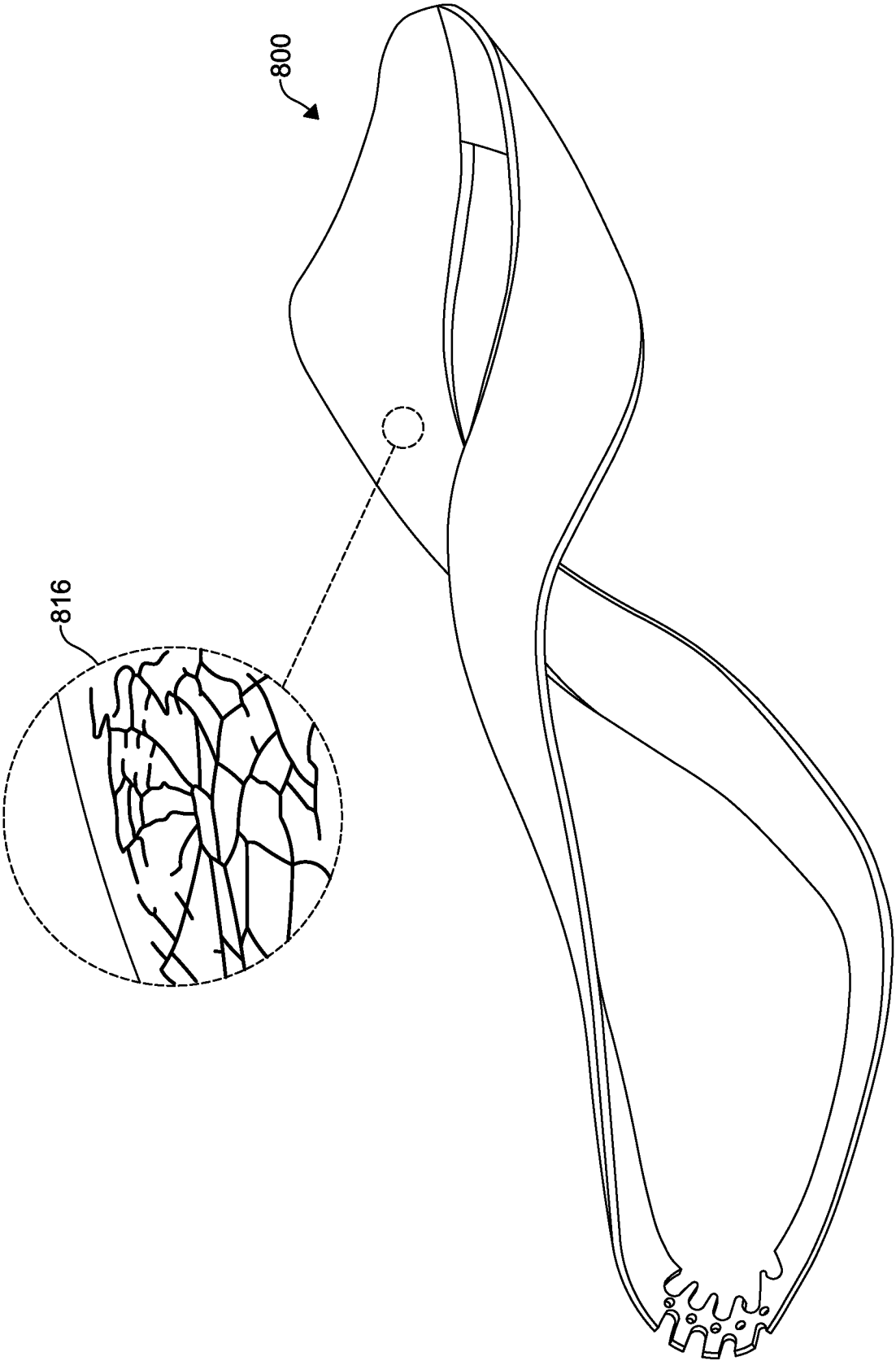
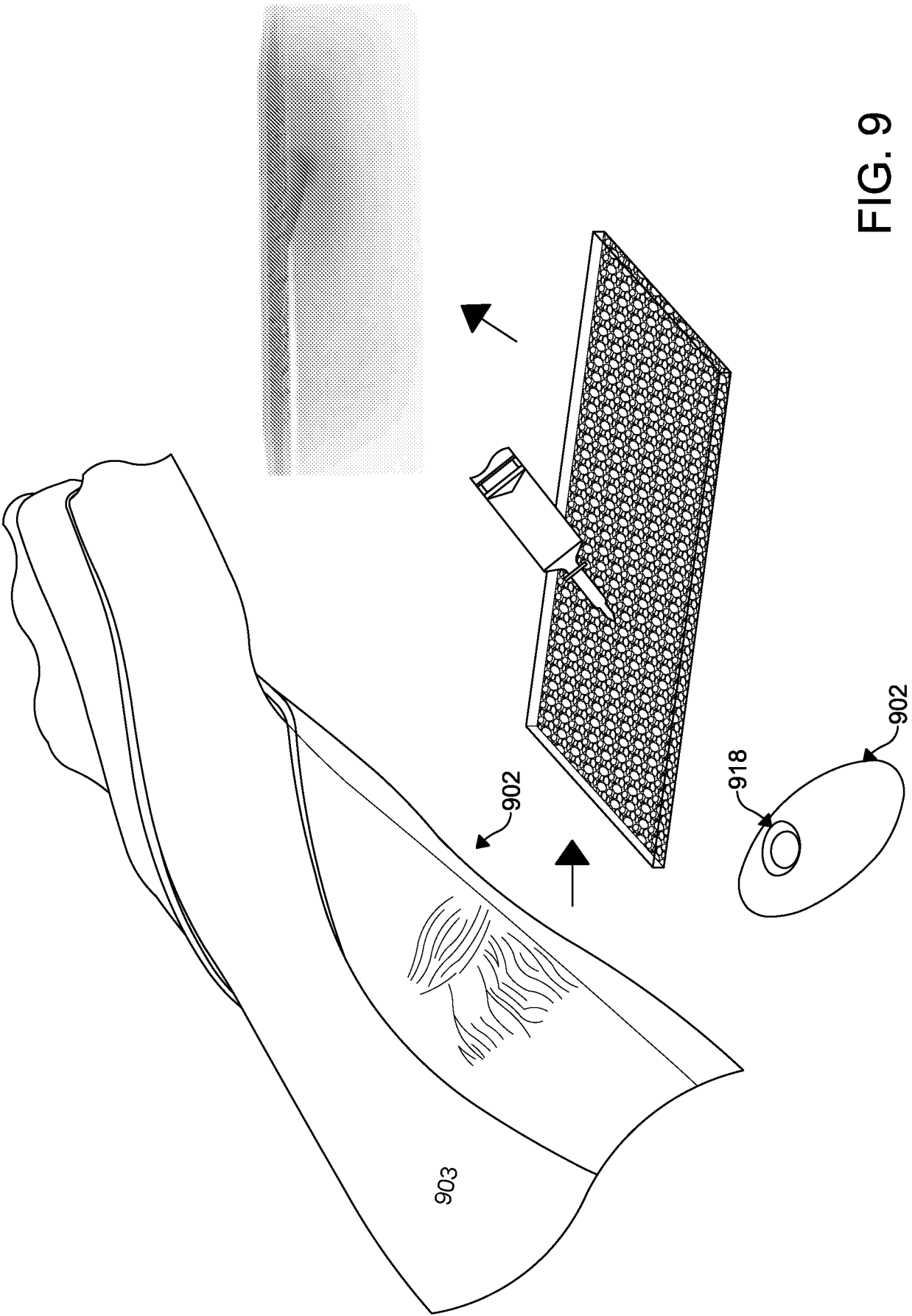


FIG. 8



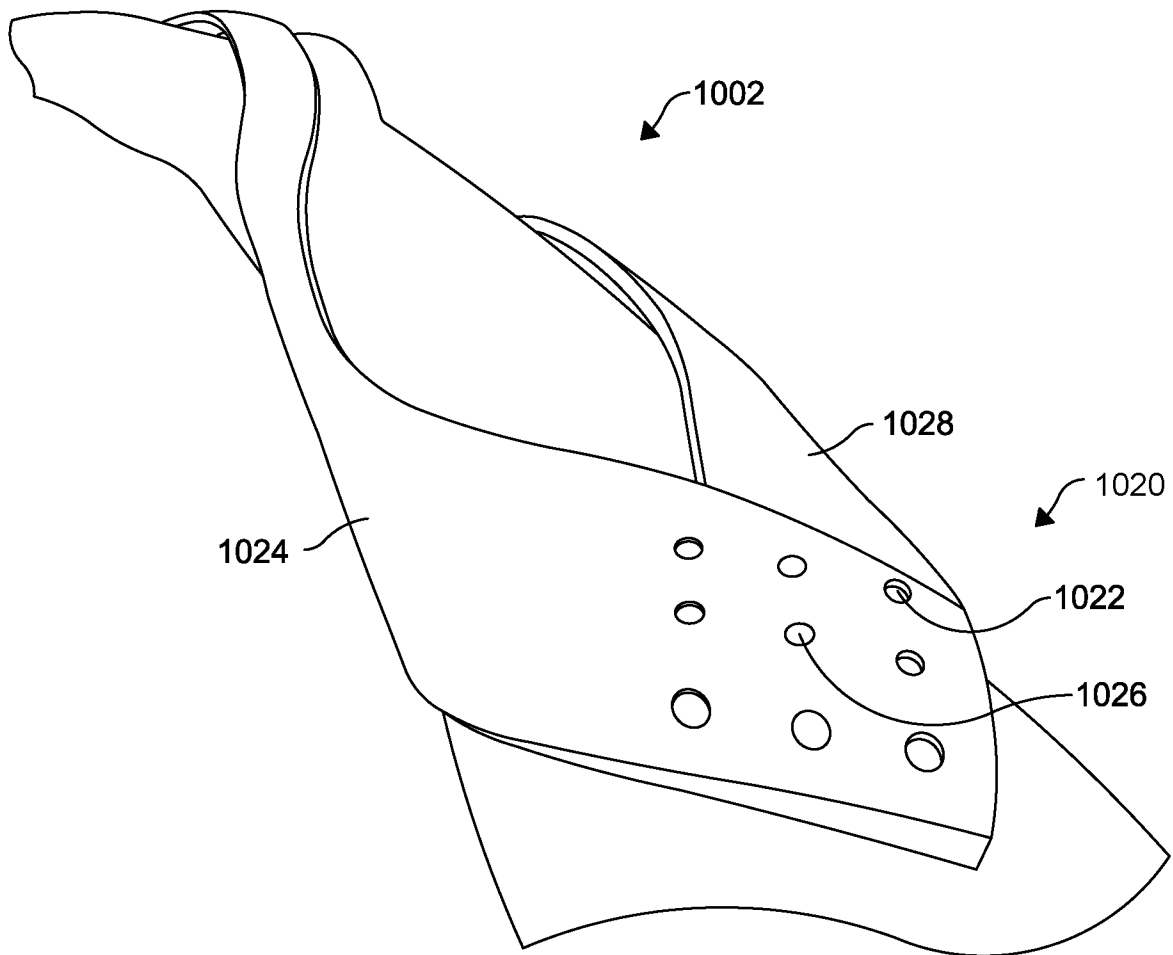


FIG. 10

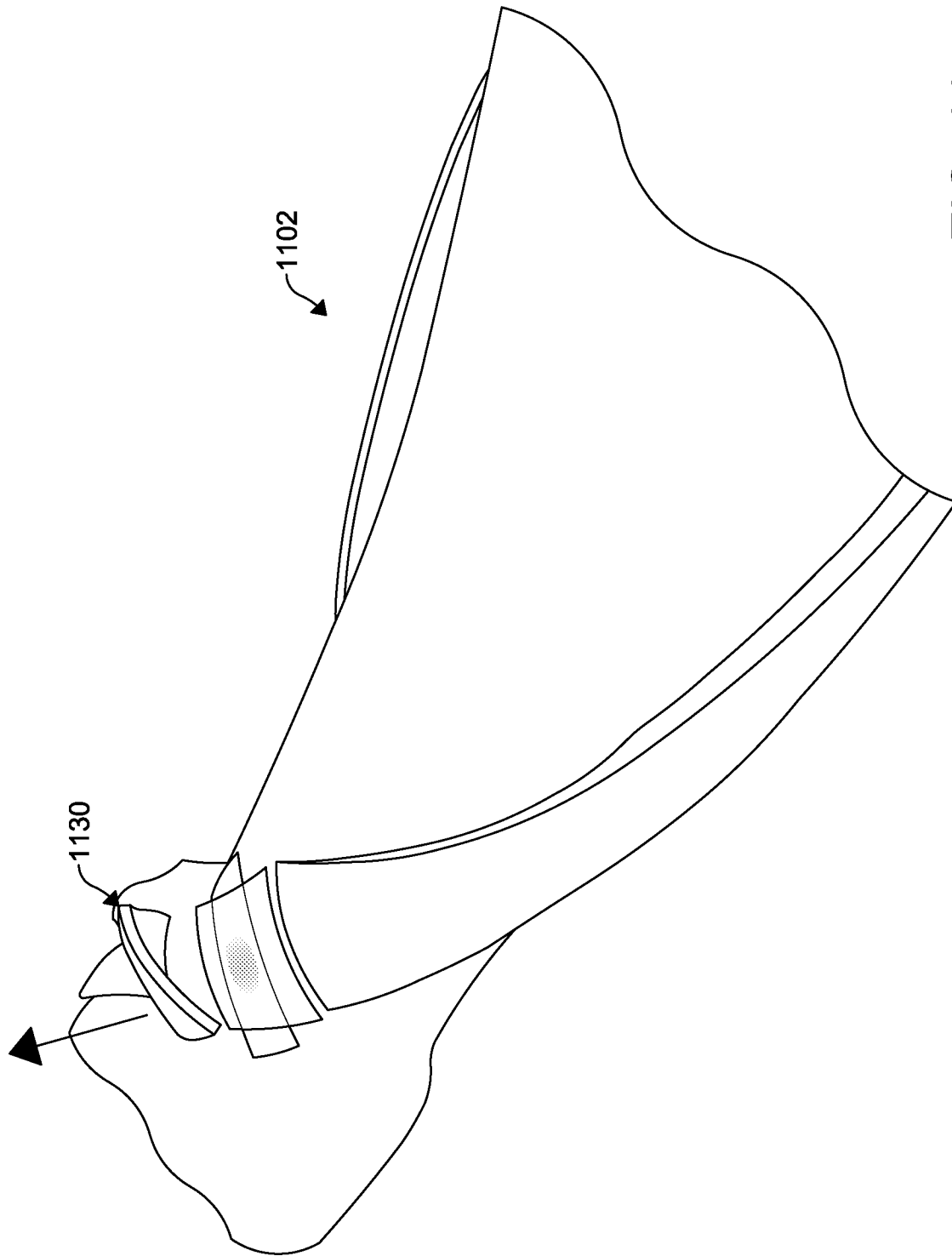


FIG. 11

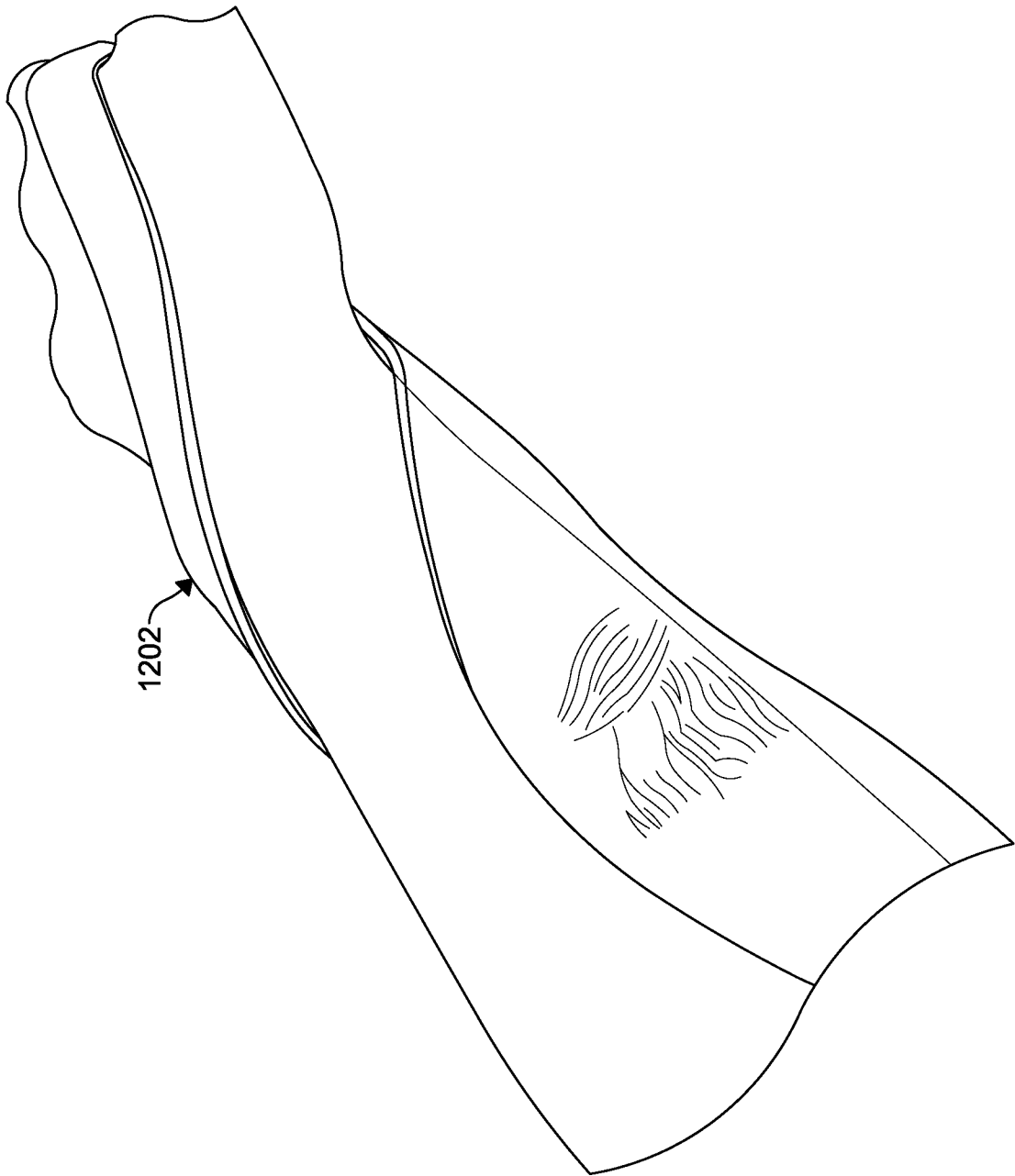


FIG. 12

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2017/055434

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61F13/04
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)

A61F G06F

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)

EP0-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.
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Y	paragraphs [0004], [0014], [0016], [0018], [0028], [0075], [0076], [0127], [0062], [0086] - [0088], [0130], [0119], [0120], [0122]	5, 15-18
Y	WO 96/03100 A1 (SMITH & NEPHEW [GB]; PENROSE JANE EDITH [GB]) 8 February 1996 (1996-02-08) page 4, paragraph 1; claims 1,5,6,7	5, 15, 17, 18
Y	WO 2014/085913 A1 (GIBEAULT JEAN-PIERRE [CA]) 12 June 2014 (2014-06-12) claims 1-39	1

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

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search

1 December 2017

Date of mailing of the international search report

08/12/2017

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Authorized officer

Gennari, Silvia

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2017/055434

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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