US 20240417897A1

(19) United States

(12) Patent Application Publication

Podhajny et al.

(10) Pub. No.: US 2024/0417897 A1

(43) Pub. Date: Dec. 19, 2024

(54) **WEFT KNIT FABRIC WITH ELECTRICAL COMPONENTS**

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(21) Appl. No.: **18/667,837**

(22) Filed: **May 17, 2024**

Related U.S. Application Data

(60) Provisional application No. 63/507,847, filed on Jun. 13, 2023.

Publication Classification

(51) **Int. Cl.**

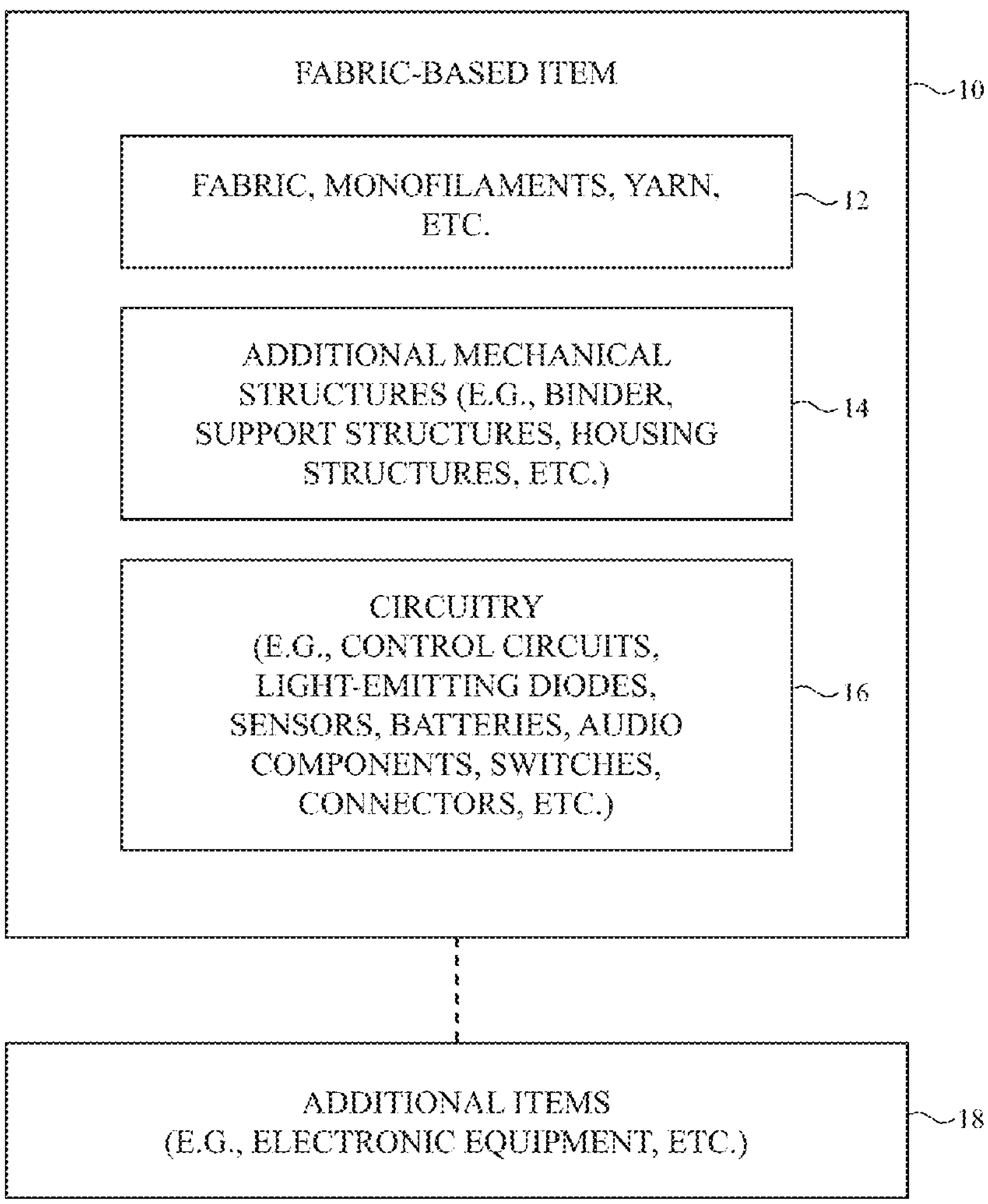
D04B 1/22	(2006.01)
D03D 1/00	(2006.01)
D04B 1/10	(2006.01)
D04B 1/16	(2006.01)
D04B 21/14	(2006.01)

(52) **U.S. Cl.**

CPC ***D04B 1/22*** (2013.01); ***D03D 1/0088*** (2013.01); ***D04B 1/102*** (2013.01); ***D04B 1/16*** (2013.01); ***D04B 21/145*** (2013.01); *D10B 2401/16* (2013.01)

(57) **ABSTRACT**

Knitting equipment may be used to form weft knit fabric. A conductive strand may be coupled to a weft knit fabric layer using stitches such as tuck stitches, knit stitches, and floats. An electrical component may be mounted to a float and electrically connected to the conductive strand. A double knit fabric may include first and second outer weft knit layers joined by a connecting strand. The electrical component may be mounted to an outer weft knit layer or the connecting strand. The electrical component may have first and second portions that attach together to trap a conductive strand between the first and second portions. The electrical component may have a through-hole that receives a conductive loop in the fabric. A circular knit fabric may include a conductive strand that spirals around a longitudinal axis and that has connected segments and electrically isolated segments.



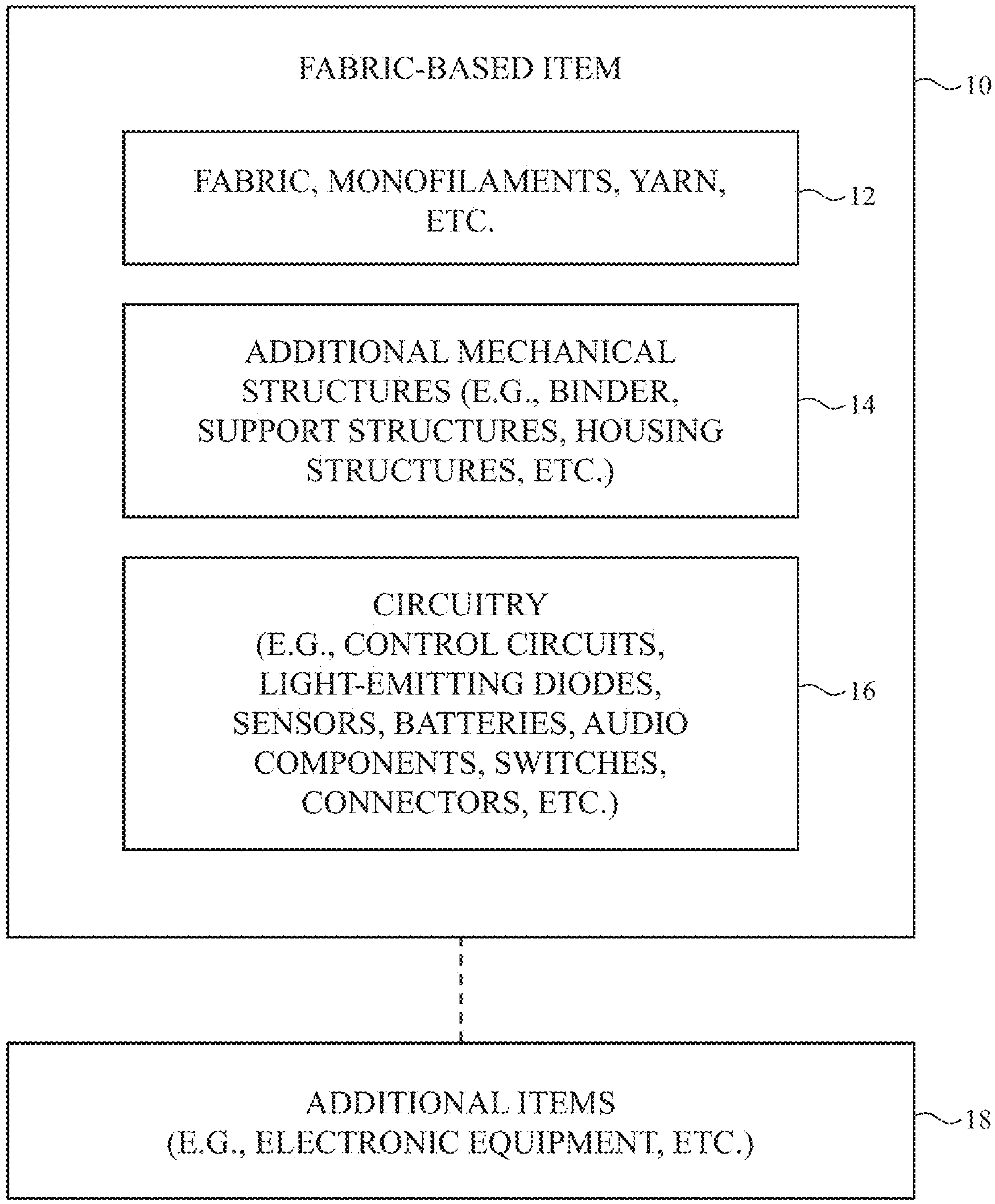

FABRIC-BASED ITEM
10
FABRIC, MONOFILAMENTS, YARN, ETC.
12
ADDITIONAL MECHANICAL STRUCTURES (E.G., BINDER, SUPPORT STRUCTURES, HOUSING STRUCTURES, ETC.)
14
CIRCUITRY (E.G., CONTROL CIRCUITS, LIGHT-EMITTING DIODES, SENSORS, BATTERIES, AUDIO COMPONENTS, SWITCHES, CONNECTORS, ETC.)
16
ADDITIONAL ITEMS (E.G., ELECTRONIC EQUIPMENT, ETC.)
18

FIG. 1

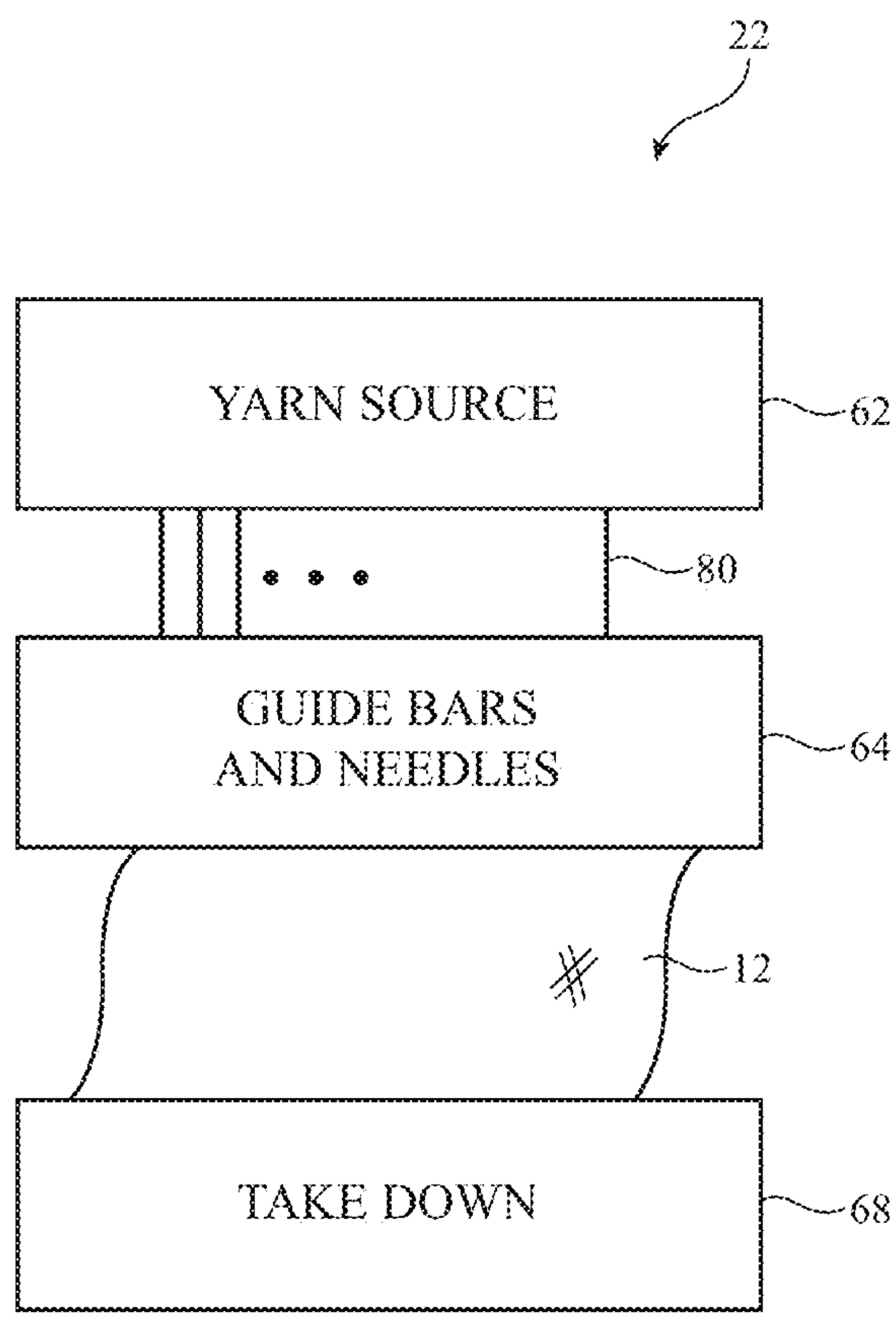


FIG. 2

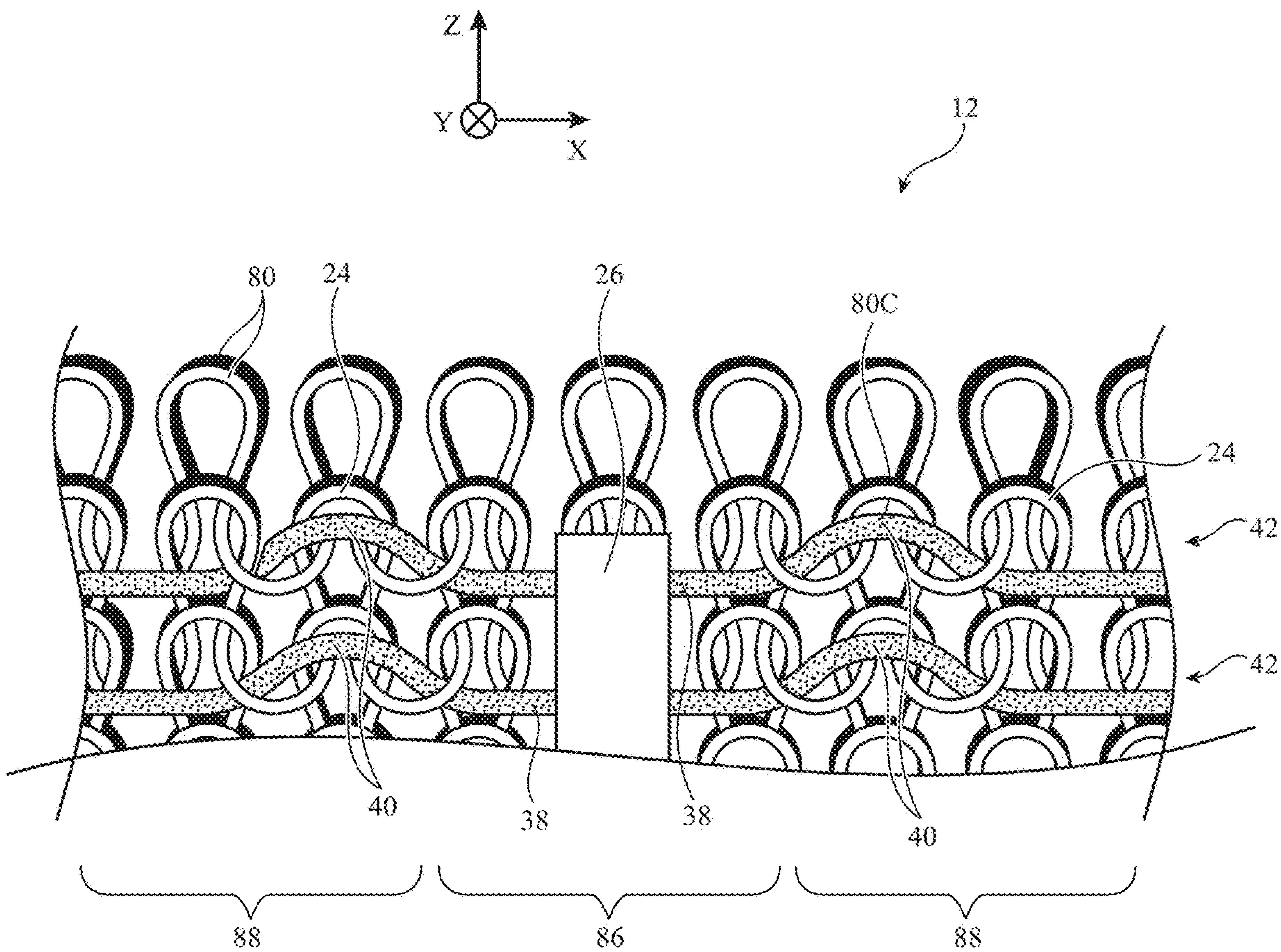


FIG. 3

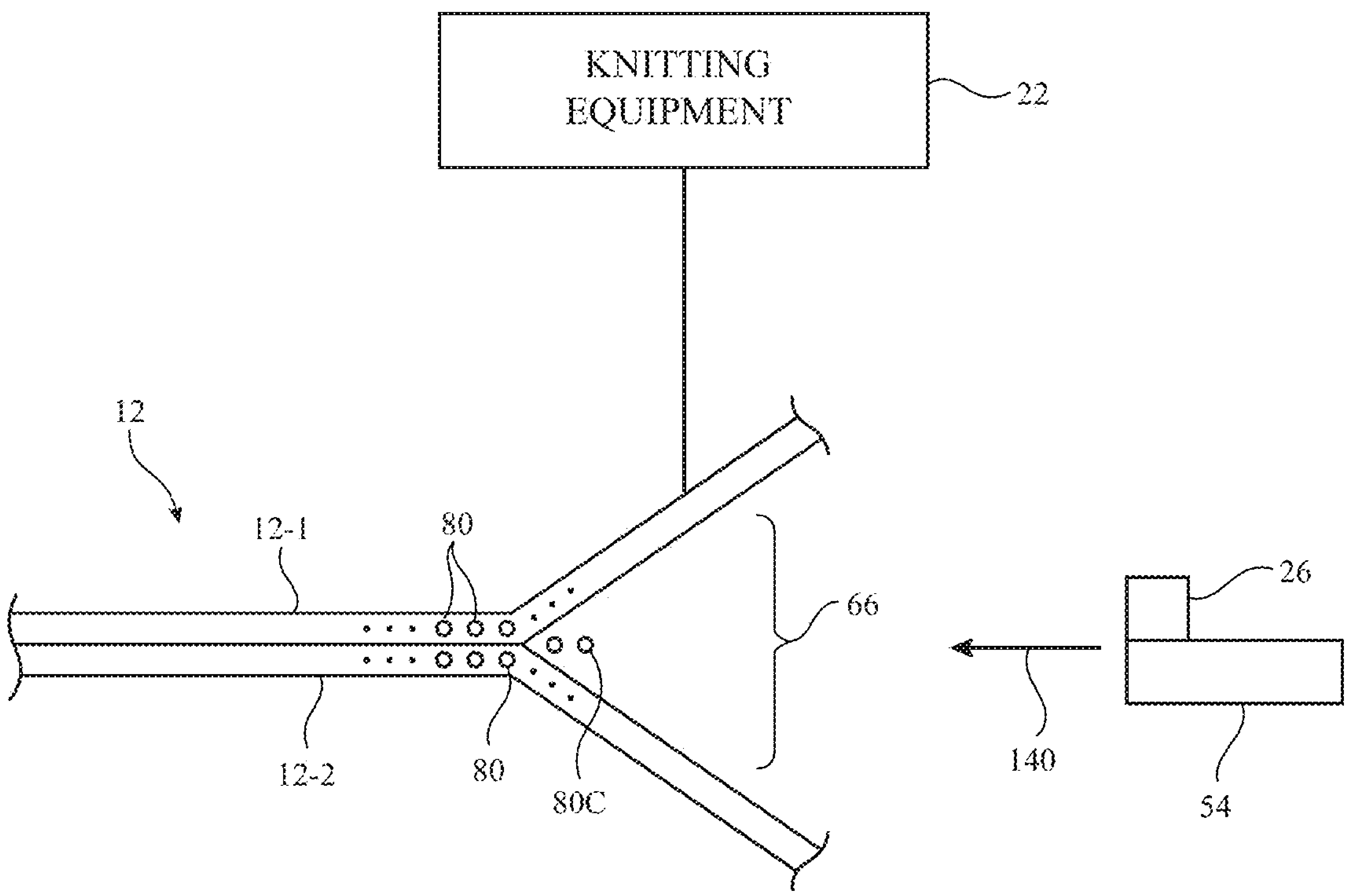


FIG. 4

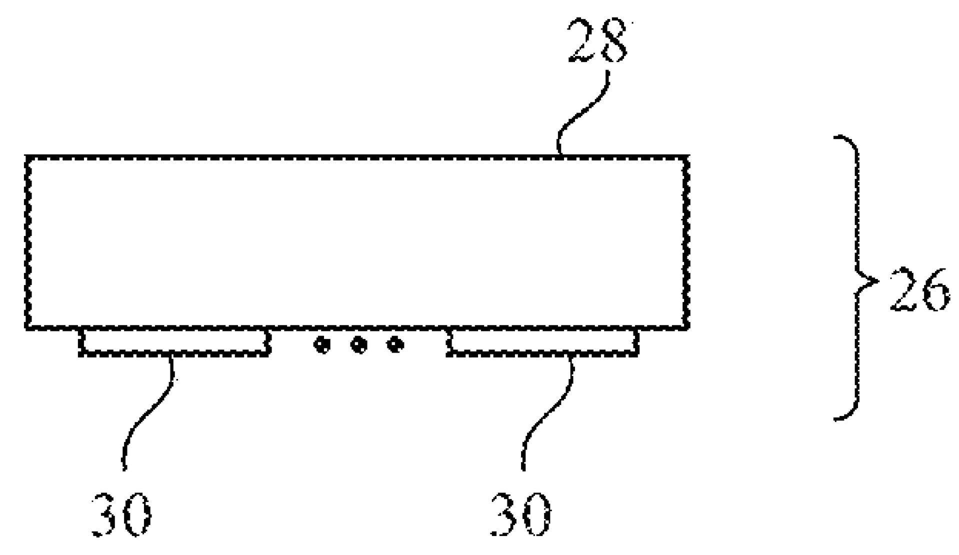


FIG. 5

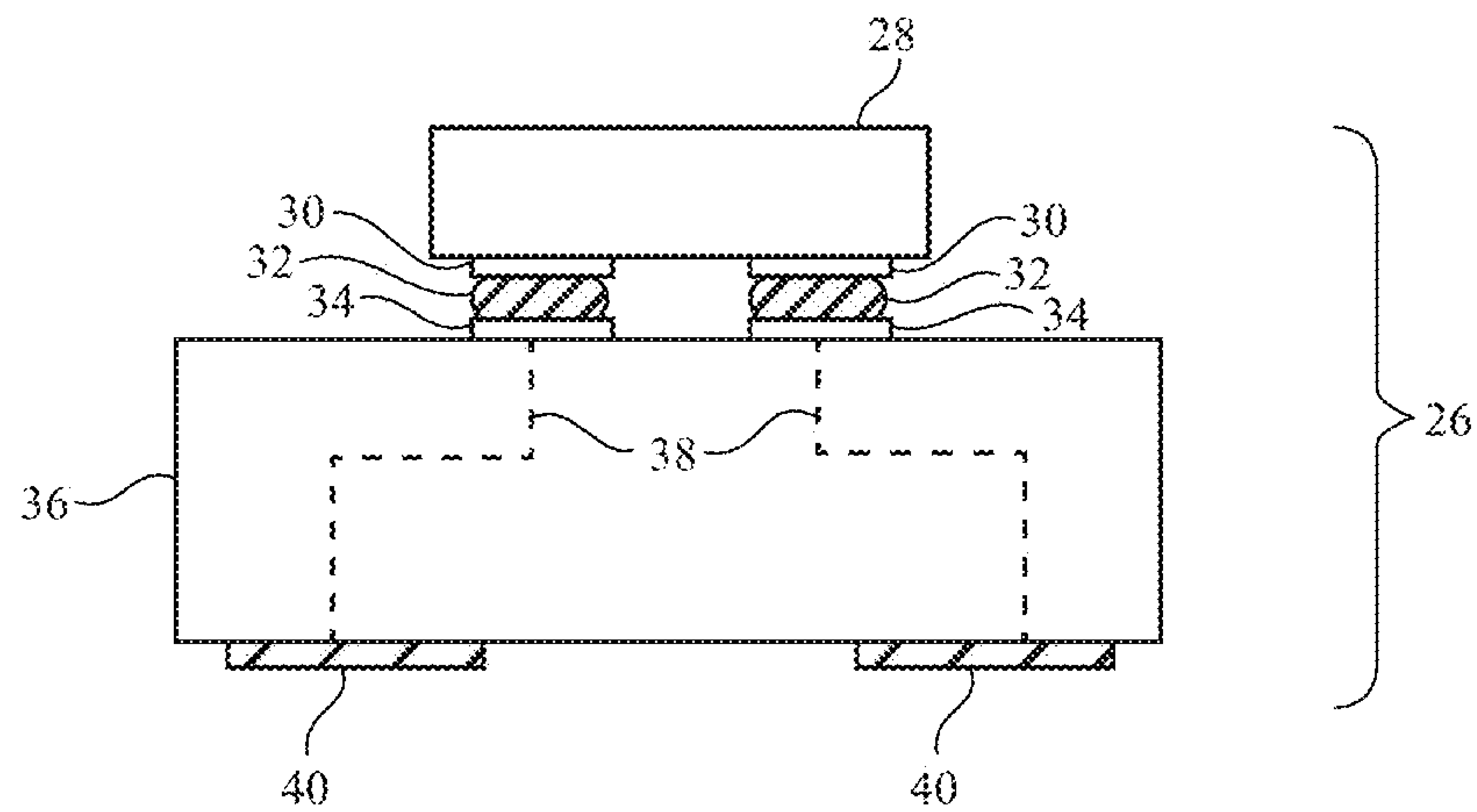


FIG. 6

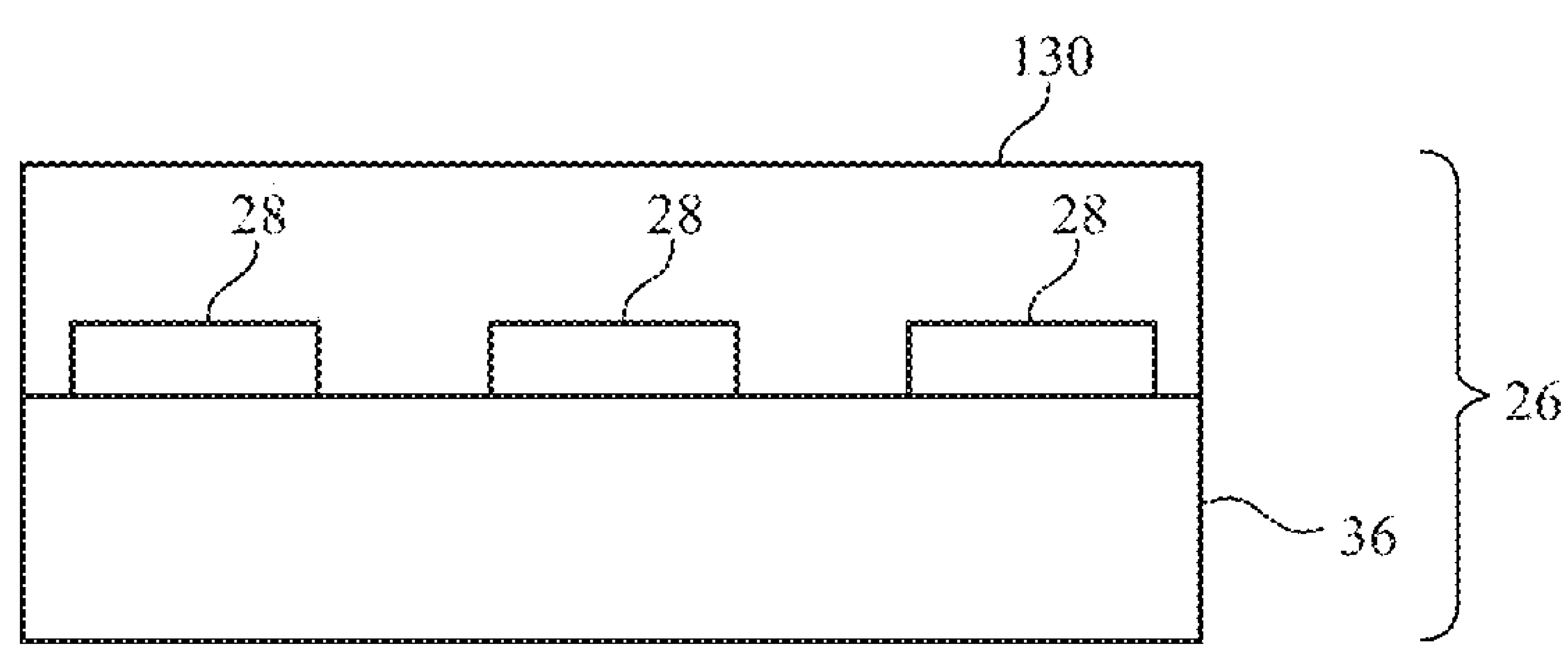


FIG. 7

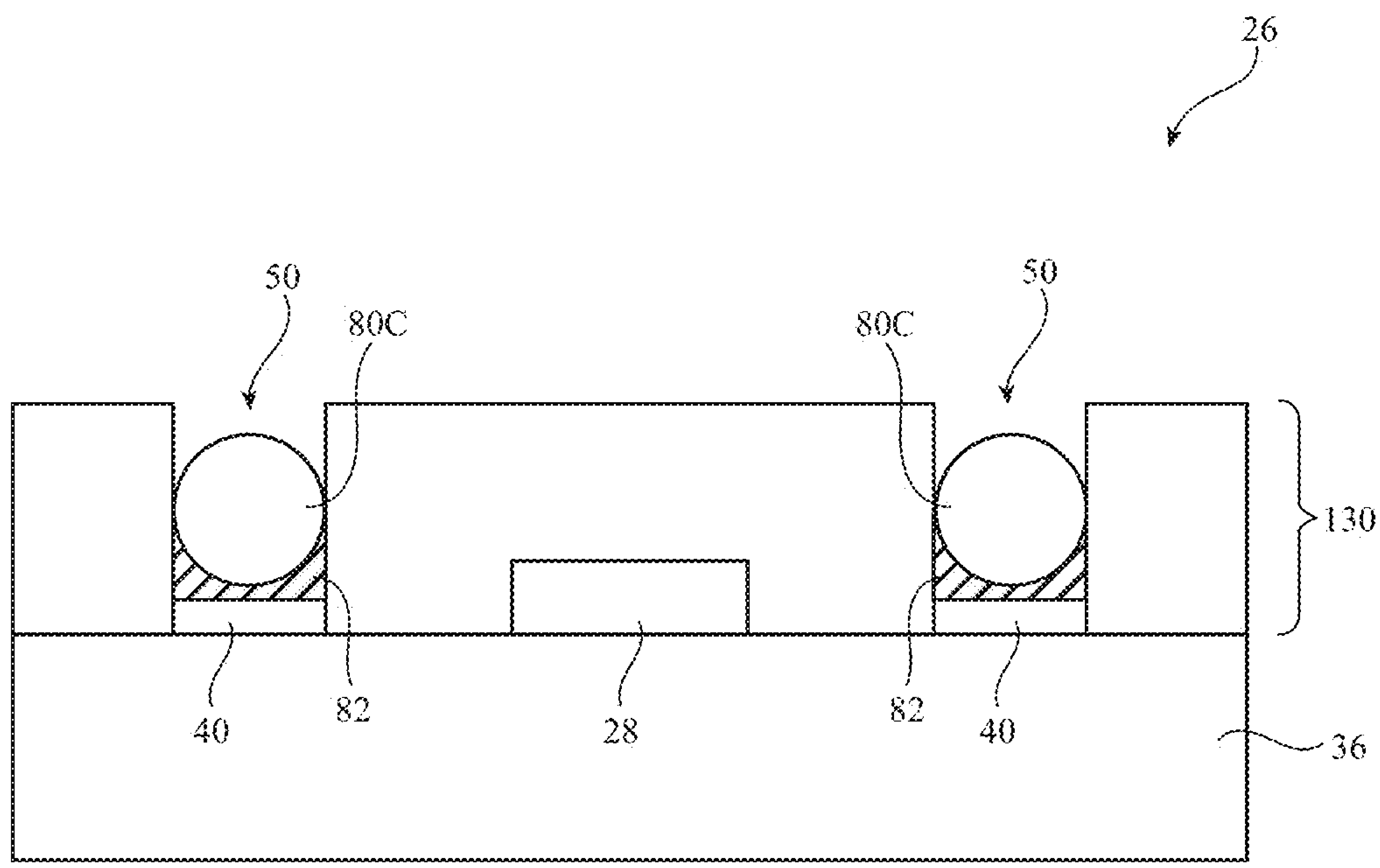


FIG. 8

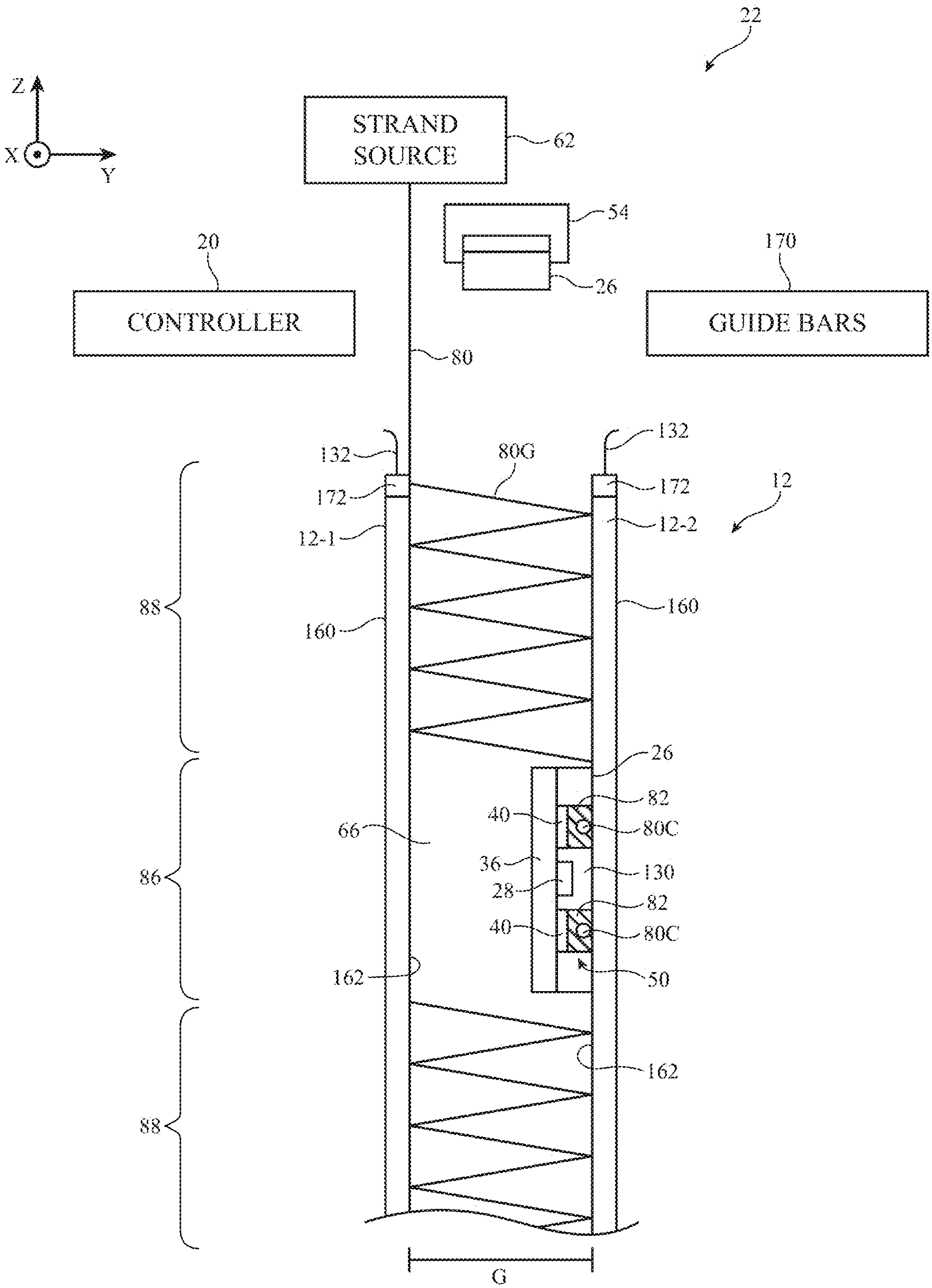

22
Z
X
Y
STRAND SOURCE
62
54
26
20
170
CONTROLLER
GUIDE BARS
80
132
80G
132
172
172
12
12-1
12-2
88
160
160
26
82
40
80C
66
36
130
86
28
82
40
80C
50
162
162
88
G

FIG. 9

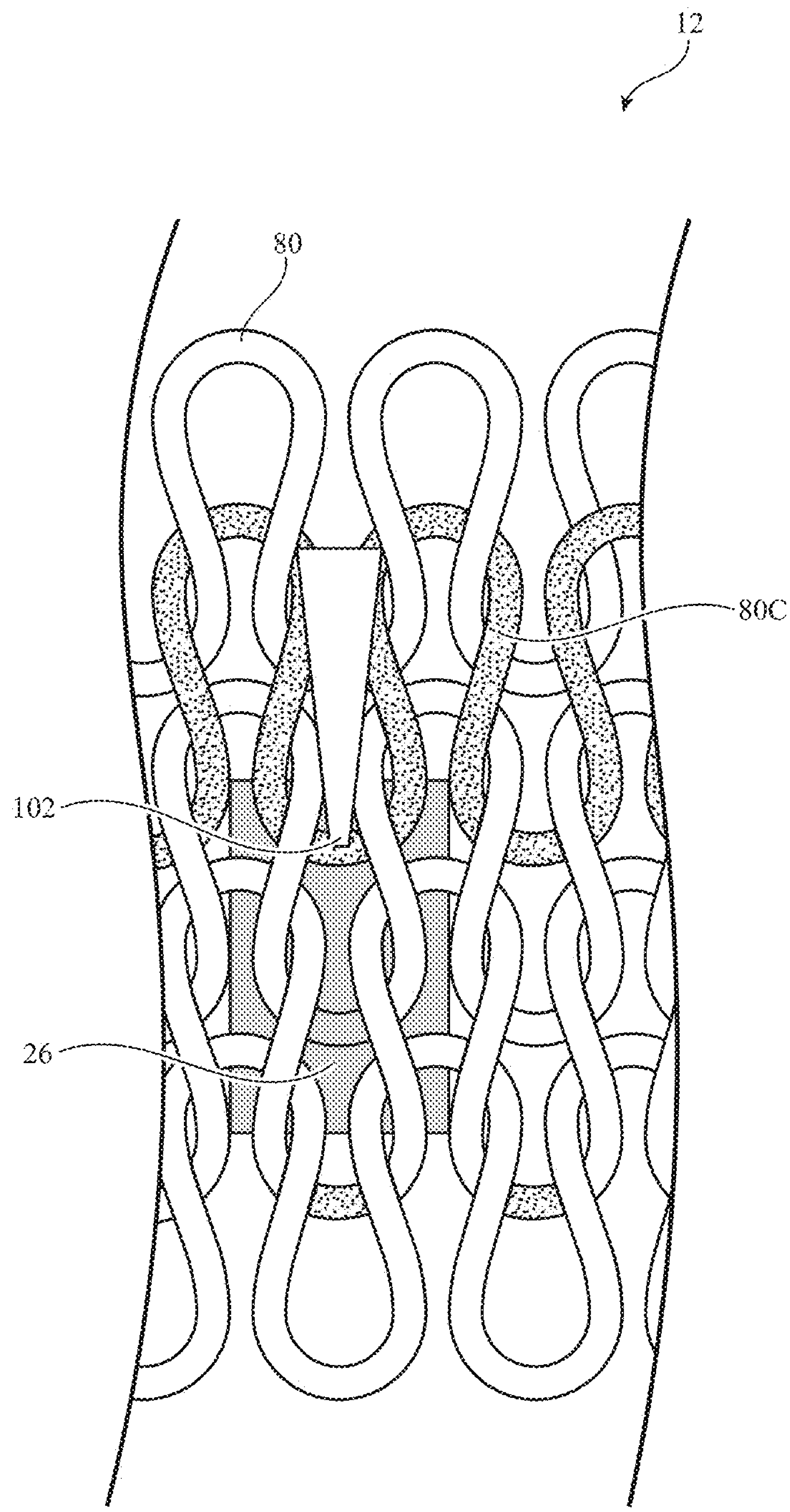


FIG. 10

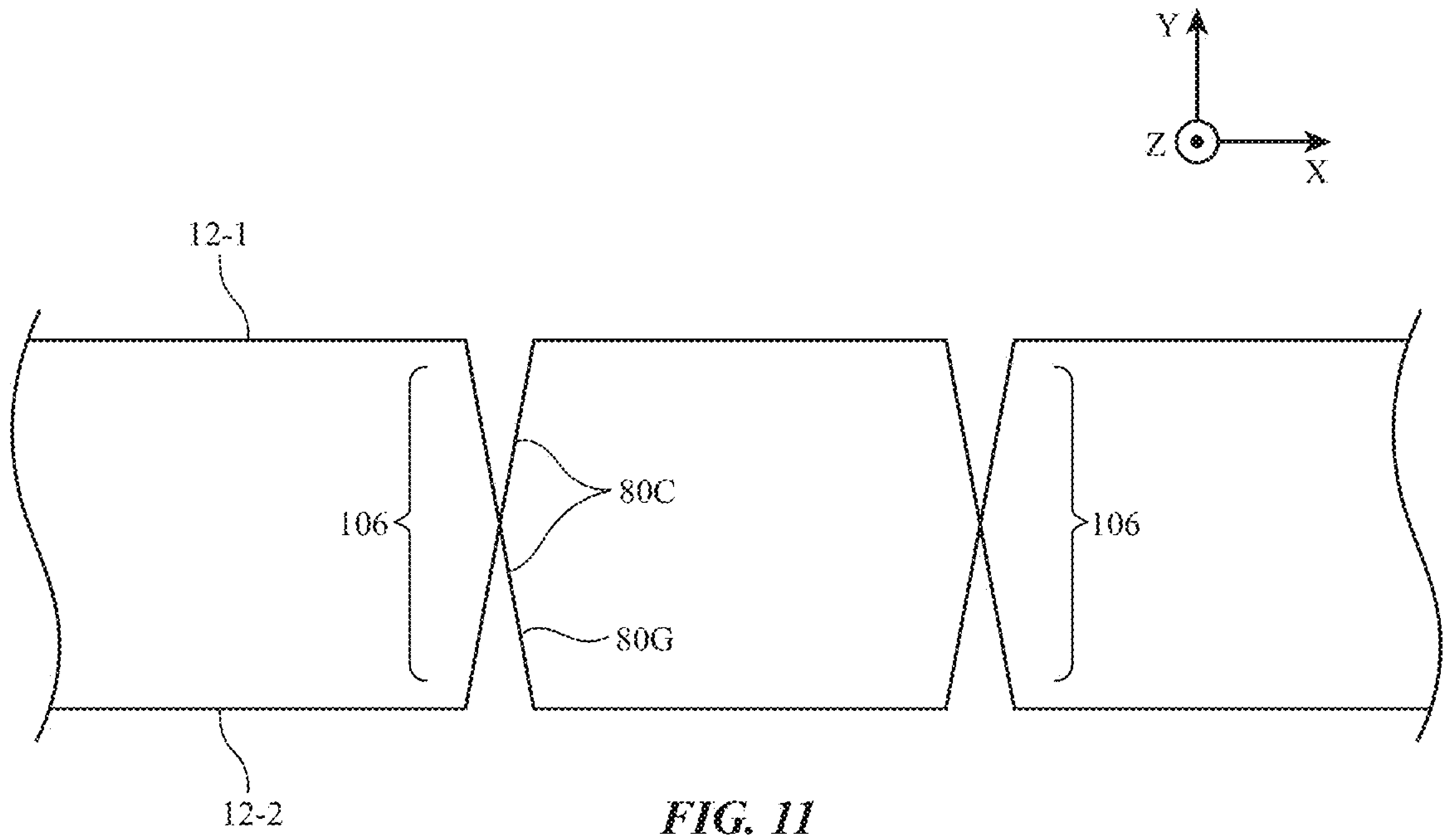


FIG. 11

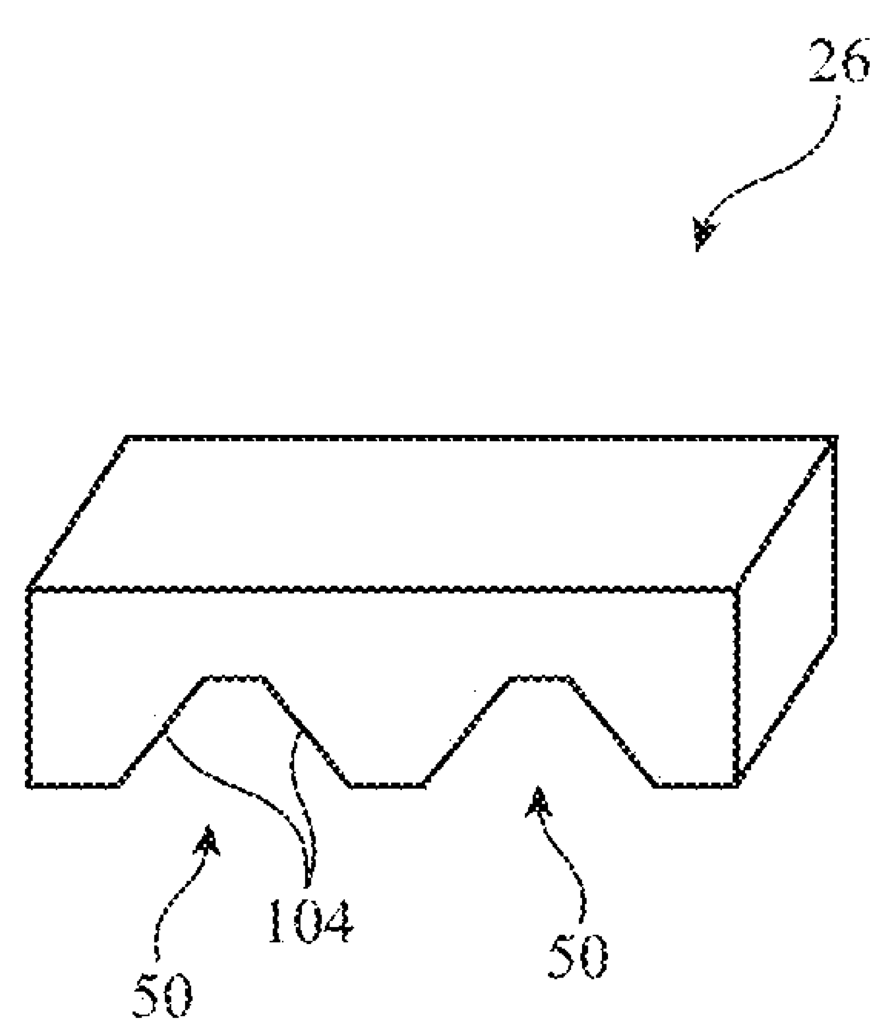


FIG. 12

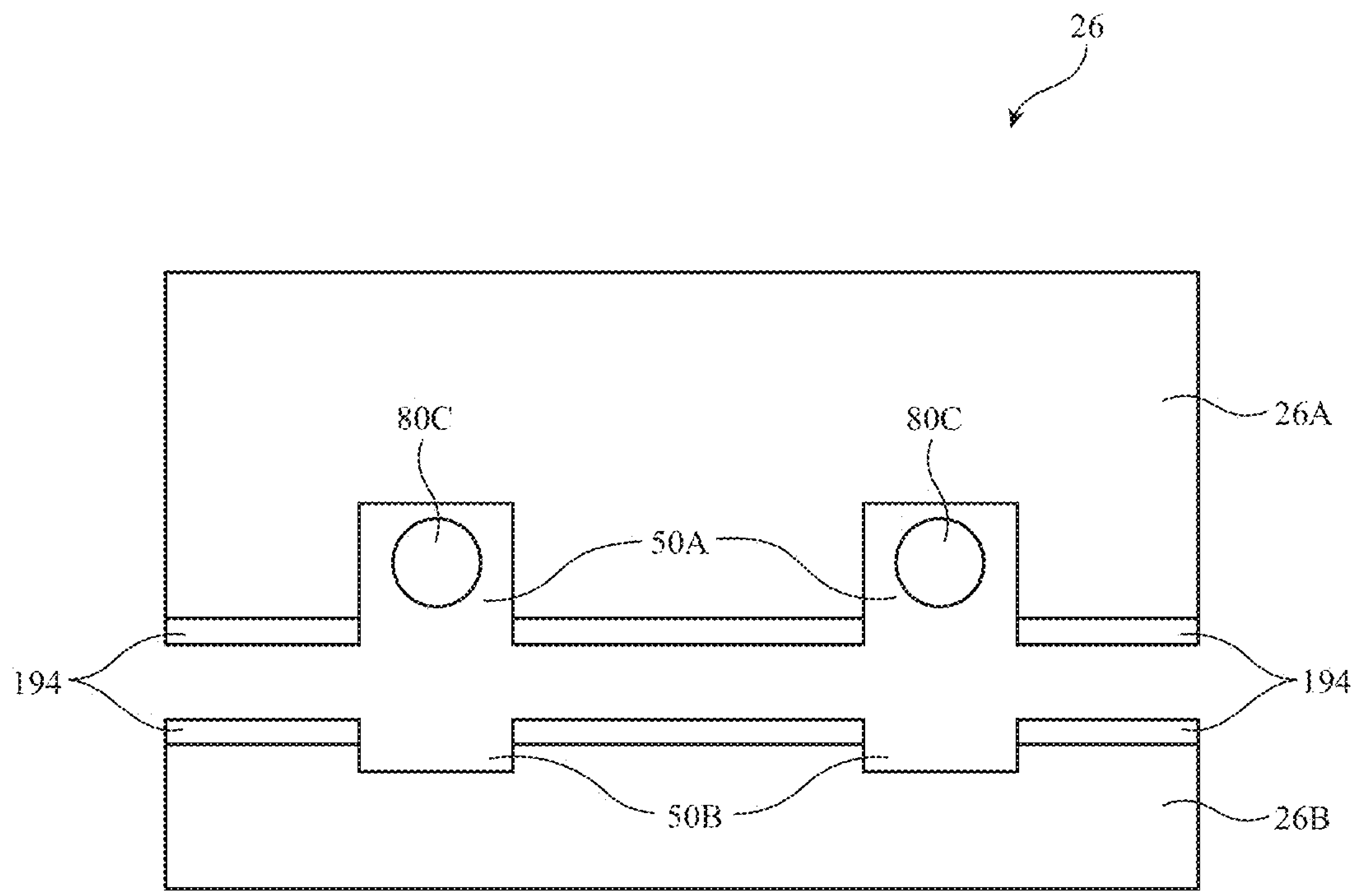


FIG. 13

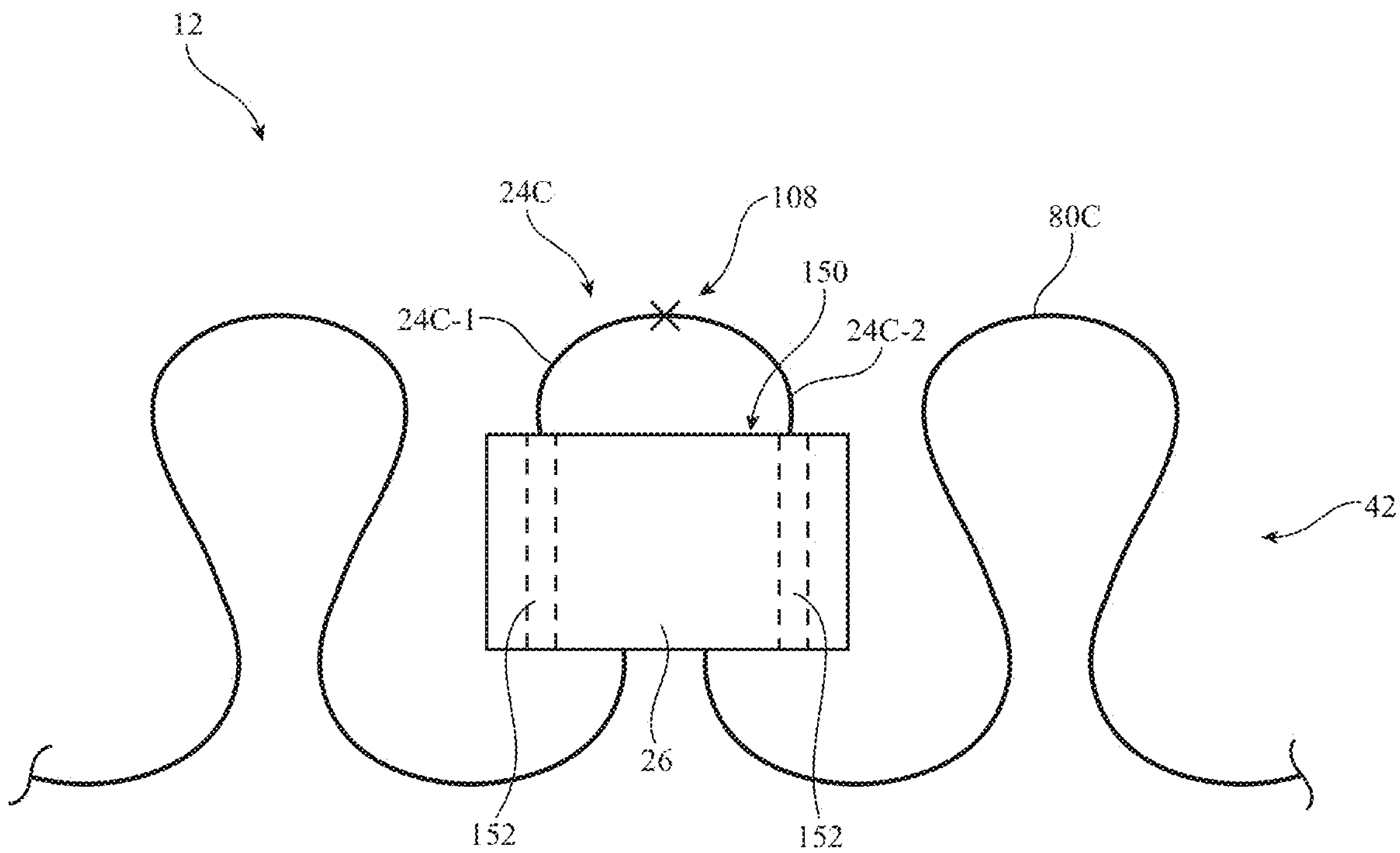


FIG. 14

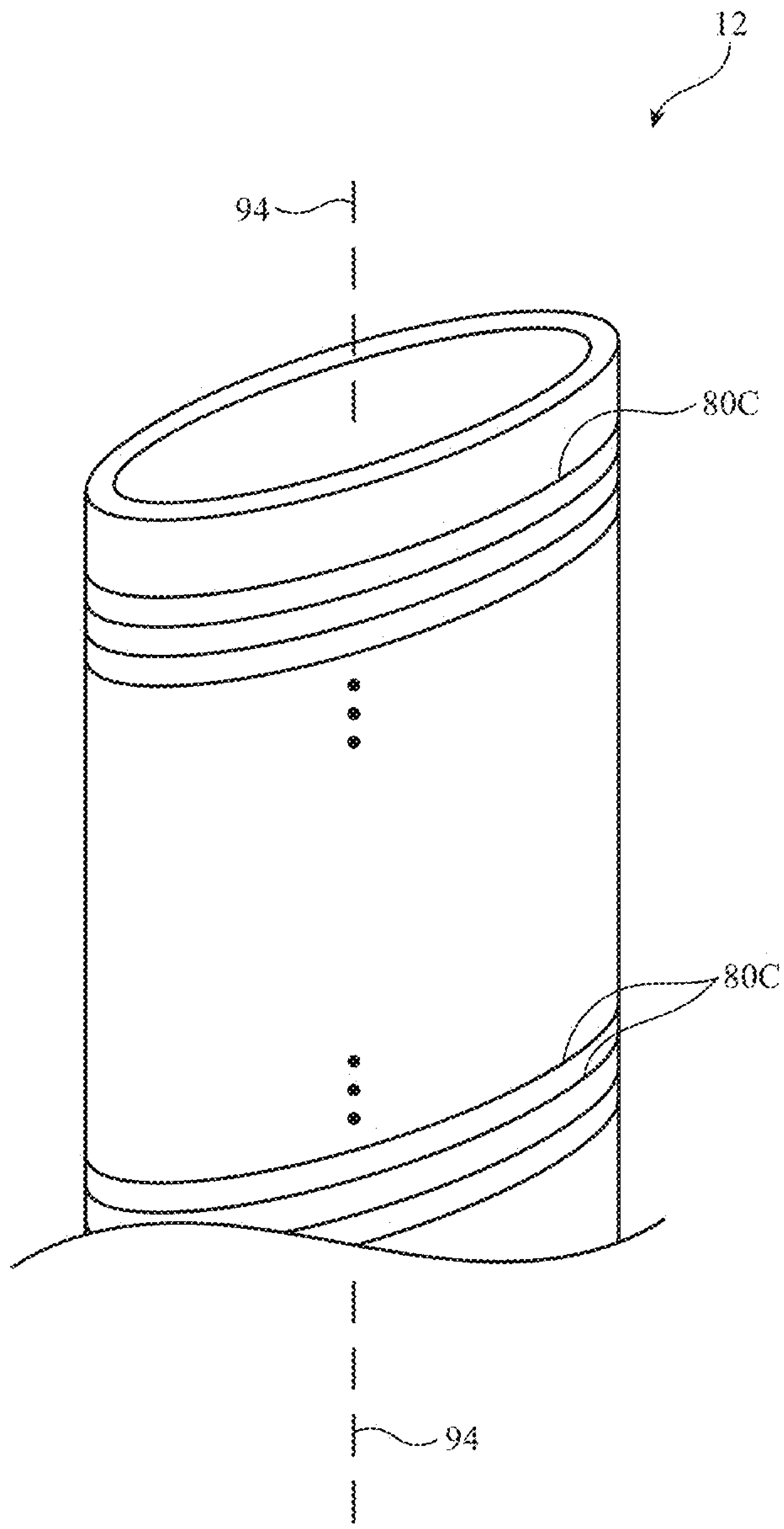


FIG. 15

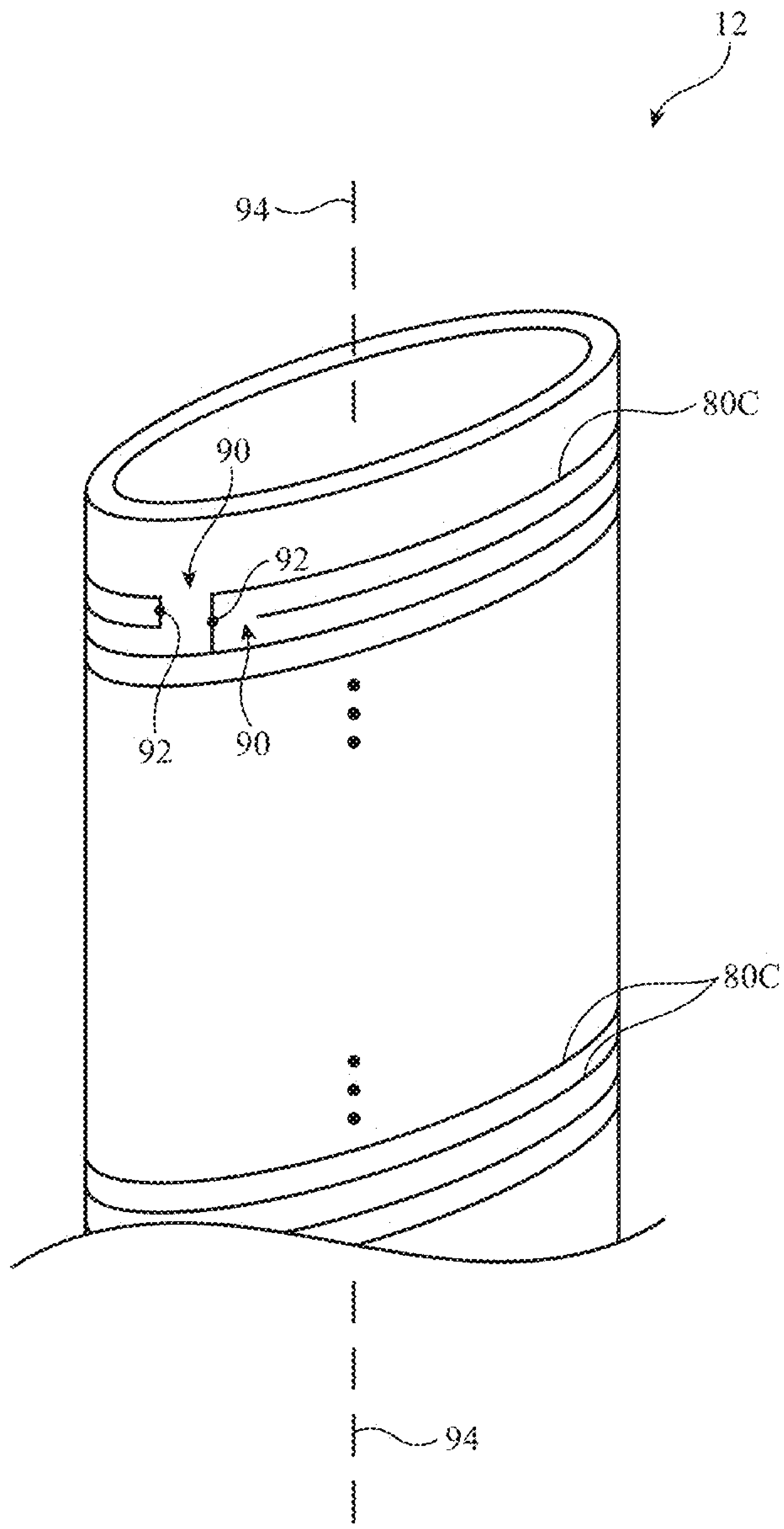


FIG. 16

WEFT KNIT FABRIC WITH ELECTRICAL COMPONENTS

[0001] This application claims the benefit of U.S. provisional patent application No. 63/507,847, filed Jun. 13, 2023, which is hereby incorporated by reference herein in its entirety.

FIELD

[0002] This relates generally to items with fabric and, more particularly, to items with fabric and electrical components.

BACKGROUND

[0003] It may be desirable to form bags, furniture, clothing, and other items from materials such as fabric. Fabric items generally do not include electrical components. It may be desirable, however, to incorporate electrical components into fabric to provide a user of a fabric item with enhanced functionality.

[0004] It can be challenging to incorporate electrical components into fabric. Fabric is flexible, so it can be difficult to mount structures to fabric. Electrical components must be coupled to signal paths (e.g., signal paths that carry data signals, power, etc.), but unless care is taken, signal paths may be damaged, or components may become dislodged as fabric is bent and stretched.

[0005] It would therefore be desirable to be able to provide improved techniques for incorporating electrical components into items with fabric.

SUMMARY

[0006] Knitting equipment may be provided with individually adjustable components. The use of individually adjustable components may allow electrical components to be inserted into the fabric during the creation or formation of the fabric.

[0007] Knitting equipment may be used to form weft knit fabric. The weft knit may include strands that form courses of loops. Some of the strands may be conductive. For example, a conductive strand may be coupled to a weft knit fabric layer using stitches. The stitches may include tuck stitches and/or knit stitches. The conductive strand may have one or more floats that pass over loops in the weft knit fabric layer. An electrical component may be mounted to the float and electrically connected to the conductive strand.

[0008] A double knit fabric may include first and second outer weft knit layers joined by a connecting strand. The electrical component may be mounted to one or both of the outer weft knit layers or may be mounted to the connecting strand. The electrical component may be located in a pocket between the outer weft knit layers.

[0009] The electrical component may have grooves that receive conductive strands. The grooves may have sloped sidewalls to accommodate machine tolerances and to allow space for solder to enter the groove. The electrical component may have first and second portions and an attachment structure that couples the first and second portions together to trap a conductive strand between the first and second portions. The electrical component may have a through-hole that receives a conductive loop in the fabric. The loop may be cut into first and second conductive loop segments that are respectively coupled to first and second electrodes on the electrical component. A circular knit fabric may include a conductive strand that spirals around a longitudinal axis and that includes pairs of segments joined by electrical connections and pairs of segments that are electrically isolated from one another.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. **1** is a schematic diagram of an illustrative fabric item in accordance with an embodiment.

[0011] FIG. **2** is a schematic diagram of an illustrative knitting system in accordance with an embodiment.

[0012] FIG. **3** is a diagram of a portion of an illustrative layer of flat knit fabric to which an electrical component has been mounted in accordance with an embodiment.

[0013] FIG. **4** is a diagram illustrating how knitting equipment may be used to create fabric while an insertion tool is used to insert electrical components into the fabric in accordance with an embodiment.

[0014] FIG. **5** is a cross-sectional side view of an illustrative electrical component in accordance with an embodiment.

[0015] FIG. **6** is a cross-sectional side view of an illustrative electrical component having an electrical device mounted on an interposer in accordance with an embodiment.

[0016] FIG. **7** is a cross-sectional side view of an illustrative electrical component having a protective structure in accordance with an embodiment.

[0017] FIG. **8** is a cross-sectional side view of an illustrative electrical component having recesses for receiving strands in accordance with an embodiment.

[0018] FIG. **9** is a side view of an illustrative double knit fabric having an electrical component interposed between first and second outer flat knit layers in accordance with an embodiment.

[0019] FIG. **10** is a front view of an illustrative knit fabric showing how a soldering tool may solder an electrical component to the knit fabric after the electrical component has been inserted into the knit fabric in accordance with an embodiment.

[0020] FIG. **11** is a top view of an illustrative double knit fabric having conductive strands that travel back and forth between first and second outer flat knit layers in accordance with an embodiment.

[0021] FIG. **12** is a perspective view of an illustrative electrical component having grooves with sloped sidewalls in accordance with an embodiment.

[0022] FIG. **13** is a side view of an illustrative electrical component having first and second mating portions that mate around conductive strands in accordance with an embodiment.

[0023] FIG. **14** is a side view of an illustrative conductive strand in a knit fabric having a loop that extends through an electrical component in accordance with an embodiment.

[0024] FIG. **15** is a perspective view of an illustrative circular knit fabric having one or more continuous conductive strands that wrap around a longitudinal axis of the circular knit fabric in accordance with an embodiment.

[0025] FIG. **16** is a perspective view of the illustrative circular knit fabric of FIG. **15** in which selective connections and disconnections in the conductive strands have been made to create an electrical circuit in accordance with an embodiment.

DETAILED DESCRIPTION

[0026] Electronic devices, enclosures, and other items may be formed from fabric such as knit fabric. The knit fabric may include strands of insulating and conductive material. Conductive strands may form signal paths through the fabric and may be coupled to electrical components such as light-emitting diodes and other light-emitting devices, integrated circuits, sensors, haptic output devices, control circuitry, and other circuitry.

[0027] Interlacing equipment (sometimes referred to as intertwining equipment) may include weaving equipment, knitting equipment, braiding equipment, or any other suitable equipment used for crossing, looping, overlapping, or otherwise coupling strands of material together to form a network of strands (e.g., fabric). Knitting equipment may be provided with individually adjustable components such as needles, needle beds, guide bars, sinkers, feeders, take-down equipment, let off equipment (e.g., devices for individually dispensing and tensioning strands), strand processing and component insertion equipment, and other components for forming fabric items. The individual adjustability of these components may allow knitting operations to be performed without requiring continuous lock-step synchronization of each of these devices, thereby allowing fabric with desired properties to be knit. As an example, normal sinker movement and other knitting operations may be periodically suspended and/or may periodically be out-of-sync with other components to accommodate component insertion operations whereby electrical components (sometimes referred to as nodes or smart nodes) are inserted into the fabric during the creation or formation of the fabric.

[0028] Items such as item **10** of FIG. **1** may include fabric and may sometimes be referred to as a fabric item or fabric-based item. Item **10** may be an electronic device or an accessory for an electronic device such as a laptop computer, a computer monitor containing an embedded computer, a tablet computer, a cellular telephone, a media player, or other handheld or portable electronic device, a smaller device such as a wrist-watch device, a pendant device, a headphone or earpiece device, a device embedded in eyeglasses or other equipment worn on a user's head, or other wearable or miniature device, a television, a computer display that does not contain an embedded computer, a gaming device, a navigation device, an embedded system such as a system in which fabric item **10** is mounted in a kiosk, in an automobile, airplane, or other vehicle (e.g., an autonomous or non-autonomous vehicle), other electronic equipment, or equipment that implements the functionality of two or more of these devices. If desired, item **10** may be a removable external case for electronic equipment, may be a strap, may be a wrist band or head band, may be a removable cover for a device, may be a case or bag that has straps or that has other structures to receive and carry electronic equipment and other items, may be a necklace or arm band, may be a wallet, sleeve, pocket, or other structure into which electronic equipment or other items may be inserted, may be part of a chair, sofa, or other seating (e.g., cushions or other seating structures), may be part of an item of clothing or other wearable item (e.g., a hat, belt, wrist band, headband, etc.), or may be any other suitable item that incorporates fabric.

[0029] Item **10** may include interlaced strands of material such as monofilaments and yarns that form fabric **12**. As used herein, "interlaced" strands of material and "intertwined" strands of material may both refer to strands of material that are crossed with one another, looped with one another, overlapping one another, or otherwise coupled together (e.g., as part of a network of strands that make up a fabric). Fabric **12** may form all or part of a housing wall or other layer in an electronic device, may form internal structures in an electronic device, or may form other fabric-based structures. Item **10** may be soft (e.g., item **10** may have a fabric surface that yields to a light touch), may have a rigid feel (e.g., the surface of item **10** may be formed from a stiff fabric), may be coarse, may be smooth, may have ribs or other patterned textures, and/or may be formed as part of a device that has portions formed from non-fabric structures of plastic, metal, glass, crystalline materials, ceramics, or other materials.

[0030] The strands of material used in forming fabric **12** may be single-filament strands (sometimes referred to as fibers) or may be threads, yarns, or other strands that have been formed by interlacing multiple filaments of material together. Strands may be formed from polymer, metal, glass, graphite, ceramic, natural materials such as cotton or bamboo, or other organic and/or inorganic materials and combinations of these materials. Conductive coatings such as metal coatings may be formed on non-conductive strands (e.g., plastic cores) to make them conductive. Reflective coatings such as metal coatings may be applied to strands to make them reflective. Strands may also be formed from single-filament metal wire (e.g., bare metal wire), multifilament wire, or combinations of different materials. Strands may be insulating or conductive.

[0031] Strands in fabric **12** may be conductive along their entire lengths or may have conductive portions. Strands may have metal portions that are selectively exposed by locally removing insulation (e.g., to form connections with other conductive strand portions and/or to form connections with electrical components). Strands may also be formed by selectively adding a conductive layer to a portion of a non-conductive strand.). Threads and other multifilament yarns that have been formed from interlaced filaments may contain mixtures of conductive strands and insulating strands (e.g., metal strands or metal coated strands with or without exterior insulating layers may be used in combination with solid plastic strands or natural strands that are insulating). In some arrangements, which may sometimes be described herein as an example, fabric **12** may be a woven fabric and the strands that make up fabric **12** may include warp strands and weft strands.

[0032] Conductive strands and insulating strands may be woven, knit, or otherwise interlaced to form conductive paths. The conductive paths may be used in forming signal paths (e.g., signal buses, power lines for carrying power, etc.), may be used in forming part of a capacitive touch sensor electrode, a resistive touch sensor electrode, or other input-output device, or may be used in forming other patterned conductive structures. Conductive structures in fabric **12** may be used in carrying electrical current such as power, digital signals, analog signals, sensor signals, control signals, data, input signals, output signals, or other suitable electrical signals.

[0033] Item **10** may include additional mechanical structures **14** such as polymer binder to hold strands in fabric **12** together, support structures such as frame members, housing structures (e.g., an electronic device housing), and other mechanical structures.

[0034] To enhance mechanical robustness and electrical conductivity at strand-to-strand connections and/or strand-to-component connections, additional structures and materials (e.g., solder, crimped metal connections, welds, conductive adhesive such as anisotropic conductive film and other conductive adhesive, non-conductive adhesive, fasteners, etc.) may be used in fabric **12**. Strand-to-strand connections may be formed where strands cross each other perpendicularly or at other strand intersections where connections are desired. Insulating material can be interposed between intersecting conductive yarns at locations in which it is not desired to form a strand-to-strand connection. The insulating material may be plastic or other dielectric, may include an insulating strand or a conductive strand with an insulating coating or insulated conductive monofilaments, etc. Solder connections may be formed between conductive strands and/or between conductive strands and electrical components by melting solder so that the solder flows over conductive strands. The solder may be melted using an inductive soldering head to heat the solder, using hot air to heat the solder, using a reflow oven to heat the solder, using a laser or hot bar to heat the solder, using localized heat from reactive films, a spark source, a laser, etc., and/or using other soldering equipment. In some arrangements, outer dielectric coating layers (e.g., outer polymer layers) may be melted away in the presence of molten solder, thereby allowing underlying metal yarns to be soldered together. In other arrangements, outer dielectric coating layers may be removed prior to soldering (e.g., using laser ablation equipment or other coating removal equipment).

[0035] Circuitry **16** may be included in item **10**. Circuitry **16** may include electrical components that are coupled to fabric **12**, electrical components that are housed within an enclosure formed by fabric **12**, electrical components that are attached to fabric **12** using welds, solder joints, adhesive bonds (e.g., conductive adhesive bonds such as anisotropic conductive adhesive bonds or other conductive adhesive bonds), crimped connections, or other electrical and/or mechanical bonds. Circuitry **16** may include metal structures for carrying current, electrical components such as integrated circuits, light-emitting diodes, sensors, and other electrical devices. Control circuitry in circuitry **16** may be used to control the operation of item **10** and/or to support communications with item **18** and/or other devices.

[0036] Item **10** may interact with electronic equipment or other additional items **18**. Items **18** may be attached to item **10** or item **10** and item **18** may be separate items that are configured to operate with each other (e.g., when one item is a case and the other is a device that fits within the case, etc.). Circuitry **16** may include antennas and other structures for supporting wireless communications with item **18**. Item **18** may also interact with item **10** using a wired communications link or other connection that allows information to be exchanged.

[0037] In some situations, item **18** may be an electronic device such as a cellular telephone, computer, or other portable electronic device and item **10** may form a cover, case, bag, or other structure that receives the electronic device in a pocket, an interior cavity, or other portion of item **10**. In other situations, item **18** may be a wrist-watch device or other electronic device and item **10** may be a strap or other fabric item that is attached to item **18** (e.g., item **10** and item **18** may together form a fabric-based item such as a wrist-watch with a strap). In still other situations, item **10** may be an electronic device, fabric **12** may be used in forming the electronic device, and additional items **18** may include accessories or other devices that interact with item **10**. Signal paths formed from conductive yarns and monofilaments may be used to route signals in item **10** and/or item(s) **18**.

[0038] The fabric that makes up item **10** may be formed from yarns and/or monofilaments that are interlaced using any suitable interlacing equipment. With one suitable arrangement, which may sometimes be described herein as an example, fabric **12** may be knit fabric formed using a knitting machine. In this type of illustrative configuration, fabric may be flat knit, weft knit, warp knit, circular knit, tricot knit, double layer knit, three-dimensional knit fabric, and/or may be other suitable fabric. This is, however, merely illustrative. If desired, fabric **12** may include woven fabric, braided fabric, other suitable type of fabric, and/or a combination of any two or more of these types of fabric.

[0039] FIG. **2** is a schematic diagram of an illustrative knitting system that may be used to form fabric **12**. A weft knitting machine (e.g., a flat knitting machine, a circular knitting machine, or other suitable weft knitting machine) or other equipment may be used in forming fabric **12** from strands **80**. As shown in FIG. **2**, yarn source **62** in knitting system **22** may be used in supplying strands **80** to guide and needle structures **64**. Structures **64** may include strand guide structures (e.g., a system of movable guide bars with eyelets that guide strands **80**) and needle systems (e.g., needle guide systems that guide sets of individually adjustable needles so that the needles may interact with the strands dispensed by the guide bars). During operations, a controller may control electrically adjustable positioners in system **22** to manipulate the positions of guide bars and needles in system **22** and thereby knit strands **80** into fabric **12**. Take-down **68** (e.g., a pair of mating rollers or other equipment forming a take-down system) may be used to gather fabric **12** that is produced during knitting.

[0040] A layer of illustrative flat knit fabric **12** (sometimes referred to as weft knit fabric **12**) is shown in FIG. **3**. Weft knit fabric **12** may be formed from strands **80** that form rows **42** of loops **24** (sometimes referred as knit stitches **24**) extending across the width of the fabric. The rows **42** of loops (referred to as courses **42**) may be interlaced with one another to form weft knit fabric **12**. Strands **80** may include non-conductive strands and conductive strands such as conductive strands **80**C. If desired, non-conductive strands **80** may form an outer weft knit fabric layer and conductive strand **80**C may be formed only on one side of the outer weft knit fabric layer. This is merely illustrative, however. If desired, conductive strand **80**C may pass back and forth between the two sides of the outer weft knit fabric layer.

[0041] During knitting, control circuitry in system **22** may direct electrically adjustable positioners in system **22** to knit fabric **12** with any suitable weft knit pattern. As an example, control circuitry in system **22** may use the electrically adjustable positioners to knit conductive strands **80**C in fabric **12** in preparation for receiving electrical components such as electrical component **26**. Conductive strand **80**C may be knitted with the rest of fabric **12** and/or may be inlaid (inserted) into fabric **12** without being knit with strands **80** that make up fabric **12**.

[0042] In some arrangements, knitting system **22** may be configured to adjust the construction of fabric **12** in a given region in preparation for receiving electrical component **26** in that region. For example, fabric **12** may have a first construction in regions **88** and a second, different construction in region **86** where electrical component **26** is mounted. In region **88**, conductive strand **80**C may be interlaced with other strands **80** of fabric **12**. In the example of FIG. **3**, conductive strand **80**C forms tuck stitches **40** in fabric **12** in regions **88** to hold conductive strand **80**C in place within fabric **12**. The use of tuck stitches **40** may serve to keep conductive strand **80**C on one side of fabric **12** (e.g., an inner facing surface of fabric **12** which is hidden from view in the final fabric item **10**), while also avoiding sharp U-turns in conductive strand **80**C that may otherwise compromise the integrity of conductive strand **80**C. This is merely illustrative. If desired, conductive strand **80**C may form knit stitches (e.g., similar to loops **24**) in fabric **12** in regions **88**.

[0043] In regions **86**, conductive strand **80**C may form one or more floats such as floats **38** on fabric **12**. Floats **38** may be created by skipping needles in regions **86** during knitting to pass over one, two, three, or more than three loops **24** of the outer weft knit fabric layer before returning to the needle bed to form stitches such as tuck stitches **40** or knit stitches **24**. Floats may also be formed by moving across needle beds (e.g., in knitting systems **22** that include first and second needle beds). Electrical component **26** may be mounted to float **38** of conductive strand **80**C. If desired, electrical component **26** may have a first terminal coupled to a first conductive strand **80**C in region **86** and a second terminal coupled to a second conductive strand **80**C in region **86**. As shown in FIG. **3**, two parallel conductive strands **80**C may each have a float **38** in region **86** interposed between first and second tuck stitches **40** in regions **88**.

[0044] If desired, conductive strands **80**C may be bundled with non-conductive (e.g., insulating) strands **80** that are controlled by different feeders. For example, each conductive strand **80**C may be bundled with (e.g., sandwiched between) first and second non-conductive strands **80** that form a protective covering on conductive strand **80**C. A plating process in which the position of each of the strands in the bundle is independently controlled by a respective feeder may be used. For example, when it is desired to mount component **26** to conductive strand **80**C, a first feeder may move conductive strand **80**C back (e.g., away from the needles holding loops **24**) while the second and third feeders form a series of loops **24** with the two non-conductive strands **80** without conductive strand **80**C. The first feeder may then reengage to return conductive strand **80**C to the non-conductive strands and knitting may continue by forming loops **24** with conductive strand **80**C.

[0045] Electrical component **26** may be inserted into a pocket of fabric **12** (e.g., before or after forming fabric **12**), may be sandwiched between layers of knit fabric **12**, may be mounted on the front or back face of fabric **12**, and/or may otherwise be incorporated into fabric **12**.

[0046] In some arrangements, electrical component **26** may be mounted to fabric **12** during the knitting process. For example, knitting system **22** may knit strands **80**, including conductive strand **80**C, electrical component **26** may be mounted to conductive strand **80**C, and knitting system **22** may continue knitting strands **80** after electrical component **26** is mounted to conductive strand **80**C to thereby incorporate electrical component **26** into fabric **12**.

[0047] In other arrangements, electrical component **26** may be incorporated into fabric **12** after fabric **12** has been formed. For example, pockets, voids, or other component receiving areas may be created in fabric **12** and component **26** may be mounted in the component receiving areas after fabric **12** has been formed.

[0048] Processing operations such as removing insulation from conductive strands **80**C, soldering electrical component **26** to conductive strands **80**C, encapsulating the electrical connection between component **26** and conductive strands **80**C, and/or other processing operations may take place at the time of component insertion (e.g., during fabric formation) or may be post-processing operations that take place after component **26** has been inserted and/or after fabric **12** has been formed.

[0049] A diagram illustrating how electrical components may be inserted into fabric **12** during the formation of fabric **12** is illustrated in FIG. **4**. As shown in FIG. **4**, fabric **12** may be formed from fabric portions such as fabric portions **12-1** and **12-2**. Fabric portions **12-1** and **12-2** may be formed from interlaced strands **80**. For example, a first set of strands **80** may be used to form fabric portion **12-1** and a second set of strands **80** may be used to form fabric portion **12-2**. Fabric portions **12-1** and **12-2** may be different portions of a single layer of fabric **12**, or fabric portion **12-1** may form a first layer of fabric **12** and fabric portion **12-2** may form a second layer of fabric **12**.

[0050] Using knitting equipment **22**, strands **80** may be interlaced to form fabric **12**. Knitting equipment **22** may include the knitting system of FIG. **2** and/or may include other interlacing equipment such as weaving equipment, braiding equipment, or other suitable interlacing equipment. Knitting equipment **22** may be used to create one or more regions in fabric **12** such as pocket **66** (sometimes referred to as a gap, space, cavity, void, position, location, etc.) for receiving electrical components such as electrical component **26**. Regions in fabric **12** that receive electrical components such as pocket **66** may be formed by creating a space or gap between portions of fabric **12** such as fabric portion **12-1** and fabric portion **12-2**. The term "pocket" may be used to refer to a void between fabric portions and/or may be used to refer to a position or location between fabric portions (e.g., a position between strands of material in fabric **12**).

[0051] Electrical components may be inserted into pocket **66** during the formation of fabric **12** using component insertion equipment such as insertion tool **54**. Insertion tool **54** may hold component **26** and may position component **26** in pocket **66** during interlacing operations (e.g., by moving component **26** towards pocket **66** in direction **140**). If desired, component **26** may be electrically and mechanically connected to one or more conductive strands **80**C in pocket **66**. Following insertion and attachment of component **26**, knitting equipment **22** may continue knitting operations (which may include closing pocket **66**, if desired) to continue forming fabric **12**.

[0052] In some arrangements, processing steps such as alignment of component **26** with conductive strands **80**C, electrically connecting (e.g., soldering) component **26** to conductive strands **80**C, encapsulation of the electrical connection between component **26** and conductive strands **80**C, and/or verification of the integrity of the electrical connection between component **26** and conductive strands **80**C may be performed after component **26** is inserted into pocket **66**. An illustrative example of in-pocket soldering, for instance, is shown in FIG. **10** (described later). In other arrangements, one or more of these processing steps may be performed before or at the same time component **26** is inserted into pocket **66** for easier access to component **26**.

[0053] In some arrangements, the gap between first and second fabric portions **12-1** and **12-2** may remain in place after electrical component **26** is enclosed in fabric **12** (e.g., a space may exist between fabric portions **12-1** and **12-2** after formation of fabric **12** is complete). In other arrangements, first and second fabric portions **12-1** and **12-2** may be pulled together such that gap **66** is eliminated after electrical component **26** is enclosed in the gap (e.g., fabric portions **12-1** and **12-2** may be in contact with one another without an intervening gap after the formation of fabric **12** is complete). Fabric **12** may have a bulge where electrical component **26** is located, or fabric **12** may not have a bulge where electrical component **26** is located (e.g., the fabric may have substantially uniform thickness across locations with electrical components **26** and locations without electrical components **26**, if desired).

[0054] A side view of an illustrative electrical component of the type that may be used in item **10** is shown in FIG. **5**. Electrical components in item **10** such as illustrative electrical component **26** of FIG. **5** may include discrete electrical components such as resistors, capacitors, and inductors, may include connectors, may include batteries, may include input-output devices such as switches, buttons, light-emitting components such as light-emitting diodes, audio components such as microphones and speakers, vibrators (e.g., piezoelectric actuators that can vibrate), solenoids, electromechanical actuators, motors, and other electromechanical devices, microelectromechanical systems (MEMs) devices, pressure sensors, light detectors, proximity sensors (light-based proximity sensors, capacitive proximity sensors, etc.), force sensors (e.g., piezoelectric force sensors), strain gauges, moisture sensors, temperature sensors, accelerometers, gyroscopes, compasses, magnetic sensors (e.g., Hall effect sensors and magnetoresistance sensors such as giant magnetoresistance sensors), touch sensors, and other sensors, components that form displays, touch sensors arrays (e.g., arrays of capacitive touch sensor electrodes to form a touch sensor that detects touch events in two dimensions), and other input-output devices, electrical components that form control circuitry such as non-volatile and volatile memory, microprocessors, application-specific integrated circuits, system-on-chip devices, baseband processors, wired and wireless communications circuitry, and other integrated circuits.

[0055] Electrical components such as component **26** may be bare semiconductor dies (e.g., laser dies, light-emitting diode dies, integrated circuits, etc.) or packaged components (e.g. semiconductor dies or other devices packaged within plastic packages, ceramic packages, or other packaging structures). One or more electrical terminals such as contact pads **30** may be formed on body **28** of component **26**. Body **28** may be a semiconductor die (e.g., a laser die, light-emitting diode die, integrated circuit, etc.) or may be a package for a component (e.g., a plastic package or other dielectric package that contains one or more semiconductor dies or other electrical devices). Contacts for body **28** such as pads **30** may be protruding leads, may be planar contacts, may be formed in an array, may be formed on any suitable surfaces of body **28**, or may be any other suitable contacts for forming electrical connections to component **26**. For example, pads **30** may be metal solder pads.

[0056] As shown in the example of FIG. **6**, body **28** may be mounted on a support structure such as interposer **36**. Interposer **36** may be a printed circuit, ceramic carrier, or other dielectric substrate. Interposer **36** may be larger than body **28** or may have other suitable sizes. Interposer **36** may have a planar shape with a thickness of 700 microns, more than 500 microns, less than 500 microns, or other suitable thickness. The thickness of body **28** may be 500 microns, more than 300 microns, less than 1000 microns, or other suitable thickness. The footprint (area viewed from above) of body **28** and interposer **36** may be 10 microns×10 microns, 100 microns×100 microns, more than 1 mm×1 mm, less than 10 mm×10 mm, may be rectangular, may be square, may have L-shapes, or may have other suitable shapes and sizes.

[0057] Interposer **36** may contain signal paths such as metal traces **38**. Metal traces **38** may have portions forming contacts such as pads **34** and **40**. Pads **34** and **40** may be formed on the upper surface of interposer **36**, on the lower surface of interposer **36**, or on the sides of interposer **36**. Conductive material such as conductive material **32** may be used in mounting body **28** to interposer **36**. Conductive material **32** may be solder (e.g., low temperature or high temperature solder), may be conductive adhesive (isotropic conductive adhesive or anisotropic conductive film), may be formed during welding, or may be other conductive material for coupling electrical device pads (body pads) such as pads **30** on body **28** to interposer pads **34**. Metal traces **38** in interposer **36** may couple pads **34** to other pads such as pads **40**. If desired, pads **40** may be larger and/or more widely spaced than pads **34**, thereby facilitating attachment of interposer **36** to conductive yarns and/or other conductive paths in item **10**. Solder, conductive adhesive, or other conductive connections may be used in coupling pads **40** to conductive yarn, conductive monofilament, printed circuit traces, or other conductive path materials in item **10**.

[0058] FIG. **7** shows an example in which component **26** includes a protective structure such as protective structure **130** on interposer **36**. Protective structure **130** may, for example, be a plastic structure that completely or partially encapsulates devices **28** and interposer **36** to provide mechanical robustness, protection from moisture and other environmental contaminants, heat sinking, and/or electrical insulation. Protective structure **130** may be formed from molded plastic (e.g., injection-molded plastic, transfer molded plastic, low-pressure molded plastic, two-part molded plastic, etc.) that has been molded over devices **28** and interposer **36** or that is pre-formed into the desired shape and subsequently attached to interposer **36**, may be a layer of encapsulant material (e.g., thermoplastic) that has been melted to encapsulate devices **28**, may be a layer of polymer such as polyimide that has been cut or machined into the desired shape and subsequently attached to interposer **36**, or may be formed using other suitable methods. Illustrative materials that may be used to form protective structure **130** include epoxy, polyamide, polyurethane, silicone, other suitable materials, or a combination of any two or more of these materials. Protective structure **130** may be formed on one or both sides of interposer **36** (e.g., may completely or partially surround interposer **36**).

[0059] Protective structure **130** may be entirely opaque, may be entirely transparent, or may have both opaque and transparent regions. Transparent portions of protective structure **130** may allow light emitted from one or more devices

28 to be transmitted through protective structure 130 and/or may allow external light to reach (and be detected by) one or more devices 28. Protective structure 130 may, if desired, have different thicknesses. The example of FIG. 7 in which protective structure 130 has uniform thickness across interposer 36 is merely illustrative. In some arrangements, protective structure 130 may be an encapsulant material such as thermoplastic that has been melted to create a robust connection between component 26 and strands 80 of fabric 12. For example, protective structure 130 may surround portions of strands 80, may fill recesses, grooves, or other features in component 26 to help interlock component 26 to strands 80, and/or may fill gaps in fabric 12.

[0060] If desired, interposer 36 may be sufficiently large to accommodate multiple electrical devices each with a respective body 28. For example, one or more light-emitting diodes, sensors, microprocessors, and/or other electrical devices may be mounted to a common interposer such as interposer 36 of FIG. 7. The light-emitting diodes may be micro-light-emitting diodes (e.g., light-emitting diode semiconductor dies having footprints of about 10 microns×10 microns, more than 5 microns×5 microns, less than 100 microns×100 microns, or other suitable sizes). The light-emitting diodes may include light-emitting diodes of different colors (e.g., red, green, blue, white, etc.), infrared light, or ultraviolet light. Redundant light-emitting diodes or other redundant circuitry may be included on interposer 36. In configurations of the type shown in FIG. 7 in which multiple electrical devices (each with a respective body 28) are mounted on a common interposer, electrical component 26 may include any suitable combination of electrical devices (e.g., light-emitting diodes, sensors, integrated circuits, actuators, and/or other devices of the type described in connection with electrical component 26 of FIG. 5).

[0061] The examples of FIGS. 6 and 7 in which devices 28 are only located on one side of interposer 36 are merely illustrative. If desired, devices 28 may be mounted to both sides of interposer 36.

[0062] Electrical components 26 may be coupled to fabric structures, individual strands, printed circuits (e.g., rigid printed circuits formed from fiberglass-filled epoxy or other rigid printed circuit board material or flexible printed circuits formed from polyimide substrate layers or other sheets of flexible polymer materials), metal or plastic parts with signal traces, or other structures in item 10.

[0063] In some configurations, item 10 may include electrical connections between components 26 and conductive paths in fabric 12. As shown in FIG. 8, for example, component 26 may be coupled to conductive strands 80C of fabric 12. Conductive strands 80C (sometimes referred to as "wires") may be configured to carry electrical signals (e.g., power, digital signals, analog signals, sensor signals, control signals, data, input signals, output signals, or other suitable electrical current) to and/or from components 26. Strands 80C may be weft strands, warp strands, spacer strands, and/or any other suitable strands 80 in fabric 12. If desired, component 26 may be coupled to only a single conductive strand 80C, may be coupled to two conductive strands 80C, or may be coupled to three or more conductive strands 80C. Arrangements in which component 26 is coupled to a pair of conductive strands 80C are sometimes described herein as an illustrative example.

[0064] Component 26 may have contact pads such as pad 40. Solder or other conductive material 82 may be used to couple pads 40 to conductive strands 80C. In the example of FIG. 8, pads 40 are formed on an upper surface of interposer 36 (e.g., the same surface on which device 28 is mounted). Conductive material 82 may be used to electrically and mechanically couple component 26 to strands 80C of fabric 12. If desired, pads 40 may instead or may be additionally formed on the lower surface of interposer 36 (e.g., the surface opposite the surface on which device 28 is mounted). The example of FIG. 8 is merely illustrative.

[0065] In some configurations, it may be desirable to provide a more robust mechanical connection between component 26 (e.g., component 26 of FIG. 5, 6, 7, or 8) and fabric 12 to ensure that component 26 does not come loose when fabric 12 is bent or stretched. To increase the robustness of the connection between strands 80C and component 26, component 26 may have one or more recesses for receiving strands 80C. For example, strands 80C may each be threaded through a portion of component 26 to help secure component 26 to fabric 12. Strands 80 may be threaded through recesses, openings, trenches, grooves, holes, and/or other engagement features of component 26. The recesses, openings, trenches, grooves, holes, or other engagement features may be formed in device 28, interposer 36, protective structure 130, and/or other portions of component 26. FIG. 8 shows an example in which conductive strands 80C are received within grooves such as grooves 50 that are formed in protective structure 130. This is, however, merely illustrative. If desired, grooves 50 may instead or additionally be formed in interposer 36, device 28, and/or other portions of component 26. The location, shape, and geometry of grooves 50 of FIG. 8 are merely illustrative.

[0066] Grooves 50 (sometimes referred to as trenches, openings, notches, recesses, holes, through-holes, etc.) in protective structure 130 may be formed by removing portions of protective structure 130 (e.g., using a laser, a mechanical saw, a mechanical mill, or other equipment) or may be formed by molding (e.g., injection molding) or otherwise forming protective structure 130 into a shape that includes grooves 50. Grooves 50 may have a width between 2 mm and 6 mm, between 0.3 mm and 1.5 mm, between 1 mm and 5 mm, between 3 mm and 8 mm, greater than 3 mm, less than 3 mm, or other suitable width. If desired, trenches 50 may have different depths (e.g., to expose contact pads 40 that are located at different surface heights of interposer 36).

[0067] Grooves 50 may expose conductive pads 40 on interposer 36. Strands 80C may each be threaded through an associated one of grooves 50 in protective structure 130. Solder or other conductive material 82 may be used to electrically and mechanically couple strands 80C to conductive pads 40 in grooves 50 of protective cover 130. Because strands 80C are wedged between portions of protective cover 130, strands 80C may be resistant to becoming dislodged from interposer 36. In addition to holding strands 80C in place so that component 26 remains attached to fabric 12, grooves 50 may also be used as a physical guide for aligning component 26 relative to fabric 12 during component insertion and attachment operations. This may be beneficial when inserting and attaching component 26 to fabric 12 without line of sight.

[0068] Each strand 80C may align with an associated pad 40 on component 26. If desired, pads 40 may formed from elongated strips of conductive material (e.g., metal) that extend from one edge of interposer 36 to an opposing edge of interposer 36. This provides a large area with which to form a mechanical and electrical connection between interposer **36** and strands **80**C. The elongated shape of pads **40** may allow conductive material **82** to attach a longer portion of strand **80**C to pad **40**. The connection between pad **40** and strand **80**C may, for example, span across the width of interposer **36**, thereby providing a robust connection between interposer **36** and strand **80**C. This is, however, merely illustrative. If desired, pads **40**, conductive material **82**, and the exposed conductive portions of strands **80**C may span across less than all of the width of component **26**.

[0069] FIG. **9** is a side view of an illustrative knitting system being used to form fabric **12** with embedded components. Fabric **12** may be a single layer knit fabric (e.g., with a single layer of flat knit fabric) or fabric **12** may be a double knit fabric having first and second outer fabric layers **12-1** and **12-2**. Outer fabric layers **12-1** and **12-2** may be flat knit fabric layers (e.g., weft knit fabric layers) of the type shown in FIG. **3**. Double knit fabrics of the type shown in FIG. **9** may be formed using first and second needle beds in knitting system **22**. For example, a first bed of needles **132** may be used to knit fabric layer **12-1** and a second bed of needles **132** may be used to knit fabric layer **12-2**. The row of needles **132** that forms each bed may extend parallel to X-axis of FIG. **9**. If desired, fabric **12** may include more than two layers of weft knit fabric and/or may be formed using more than two needle beds. The arrangement of FIG. **9** is merely illustrative.

[0070] Controller **20** may control the operation of equipment **22**. Controller **20** (sometimes referred to as control circuitry **20**) may include storage and processing circuitry for implementing control functions during knitting operations. The storage may include, for example, random-access memory, non-volatile memory such as read-only memory, hard disk storage, etc. The processing circuitry may include microprocessors, microcontrollers, digital signal processors, application-specific integrated circuits, and other circuits for executing software instructions obtained from storage.

[0071] In knitting arrangements, knitting equipment **22** includes a strand source such as strand source **62**. Source **62** may supply strands **80** from a beam, a creel, cones, bobbin, or other strand dispensing structure. Source **62** may, for example, dispense strands **80** through electrically controlled dispensing rollers or other strand dispensing and tensioning equipment (e.g., a rotating drum, electrically controlled actuators, sensors, and/or other equipment that measures, controls, and/or adjusts strand feed and tension of strands **80**).

[0072] Needles **132** may have first and second support structures (first and second needle guide systems) for respectively supporting first and second sets of needles **132**. These support structures, which may sometimes be referred to as needle beds, needle guide structures, needle guides, or needle systems, may have conical shapes or may have other suitable shapes, (e.g., cylindrical shapes, cylindrical shapes with planar inserted sections, etc.). System **22** may support any suitable numbers of needles **132** (e.g., tens of needles, hundreds of needles, or more). As an example, each needle bed may support 100-400 needles **132**, at least 50 needles **132**, at least 200 needles **132**, fewer than 500 needles **132**, etc.

[0073] Guide bar system **170**, which may sometimes be referred to as guide bars, a strand guide system, yarn guide system, guide bar system, or strand guiding system, may include a series of guide bars that are used in providing needles **132** with strands **80**. Needles **132** may be moved using electrically adjustable positioners **172**. Guide bars **170** may be positioned using adjustable guide bar positioners. The separation (gap G) between the first and second beds of needles **132** can be adjusted by moving the support structures that support needles **132** (e.g., in response to control signals from controller **20**).

[0074] Strand dispensing equipment **62**, needles **132**, guide bars **170**, and/or other equipment in system **22** such as sinkers, take-down equipment, etc., may be independently controlled by controller **20**. At the same time, and in coordination with the control of these components, controller **20** may control component insertion and strand processing equipment in equipment **22** (e.g., so that light-emitting diodes, integrated circuits, sensors, and other electrical components such as component **26** can be inserted into fabric **12**).

[0075] For example, controller **20** may temporarily suspend or slow knitting operations (e.g., may temporarily suspend or slow movement of knitting components such as strand source **62**, guide bars **170**, needles **132**, and/or other equipment in system **22**) while electrically controlled strand processing equipment performs processing operations on strands **80**, while component insertion tool **54** inserts electrical components into fabric **12**, and/or while soldering operations take place (e.g., during which contacts **40** on electrical components **26** are soldered to conductive strands **80**C).

[0076] System **22** may include insulation removal tools such as lasers, heating elements, and/or other components that generate light, heat, and/or other energy for removing insulation from the exterior of insulated conductive strands **80**C. Heating tools in system **22** may include an inductive head, heating elements, a hot air source, lasers, a localized heat source, and/or other components that generate heat and/or other energy for melting solder and/or melting encapsulant material on components **26**. For example, solder **82** may be reflowed on contacts **40** to thereby solder component **26** to conductive strands **80**C. Encapsulant material such as portions of protective structure **130** may also be melted using a heating tool to form a robust mechanical connection and provide encapsulation around the electrical connection. If desired, equipment **22** may include other strand processing equipment such as components for applying coatings and/or other equipment for modifying strands **80**.

[0077] If desired, insulation may be removed from strands, solder may be reflowed, and encapsulant material may be melted using a single tool (e.g., a laser and/or heating element may be used to remove insulation, reflow solder, and melt encapsulant material at the same time and/or at different times). Arrangements where a first tool (e.g., a laser) is used to remove insulation from strands **80** and a second tool (e.g., an inductive heating tool, hot air, laser, etc.) is used to reflow solder and melt encapsulant material are sometimes described herein as an illustrative example. If desired, one or more sensors such as a pyrometer may be used to monitor the temperature of component **26**, fabric **12**, and/or other components during insulation removal operations, during solder reflow operations, and/or during the melting of encapsulant material. If desired, conductive strands in fabric **12** such as conductive strands **80**C may include non-insulated conductive strands (e.g., strands that do not include an outer insulator) and an insulation removal tool may not be needed.

[0078] Component insertion equipment for inserting components into fabric **12** during the formation of fabric **12** may include insertion tool **54**. Insertion tool **54** may include an insertion head and an electrically controlled positioner that positions the insertion head within pocket **66**. Insertion tool **54** may be used to insert components **26** (e.g., electrical components) into fabric **12**. For example, insertion tool **54** may place component **26** in pocket **66** and may align grooves **50** in component **26** with conductive strands **80**C. The exposed conductive segments of conductive strands **80**C in pocket **66** are received within grooves **50** and aligned with pads **40** of component **26**. In other arrangements, insertion tool **54** may align component **26** with segments of strands **80**C that are initially located outside of pocket **66**. In this type of scenario, component **26** may be aligned with strands **80**C, electrically connected (e.g., soldered) to strands **80**C, and encapsulated (if desired) before component **26** is inserted into pocket **66**. If desired, equipment **22** may include a spreading tool for spreading strands **80** to create an opening in fabric **12** through which component **26** may be accessed for out-of-pocket processing of component **26**.

[0079] If desired, fabric **12** may have multiple pockets **66** for multiple components **26** and/or may have multiple components **26** in each pocket **66**. If desired, components **26** may be mounted to portions of fabric **12** other than pockets **66** during the formation of fabric **12** (e.g., may be mounted to an upper or lower surface of fabric **12** and/or to other portions of fabric **12**). Pockets **66** may be staggered with respect to one another or formed in one line. Multiple components **26** in one pocket **66** may be staggered with respect to one another or formed in one line. If desired, multiple components **26** may be electrically connected to the same pair of conductive strands and/or a component may have a first terminal coupled to one portion of a strand and a second terminal coupled to a second portion of the same strand. Pocket **66** may be entirely opaque, may be entirely transparent, or may have both opaque and transparent regions. Transparent portions of pocket **66** may allow light emitted from one or more devices **28** to be transmitted through fabric **12** and/or may allow external light to reach (and be detected by) one or more devices **28**.

[0080] Insertion tool **54** may include one or more components for mounting electrical components **26** in fabric **12**. For example, insertion tool **54** may include an electrically controlled actuator for regulating the release of components **26** from insertion tool **54** (e.g., when component **26** is in pocket **66**), may include sensors for monitoring the positions of strands **80**, sensors for monitoring the positions of components **26**, sensors for measuring temperature, sensors for measuring resistance, or other devices for gathering input and/or data on the environment surrounding insertion tool **54**.

[0081] If desired, needles may transfer strands **80** and/or loops of strands **80** from one needle bed to the opposing needle bed to form a connecting layer between fabric layers **12-1** and **12-2**. As shown in FIG. **9**, for example, fabric **12** may include connecting strands **80**G that join outer fabric layers **12-1** and **12-2** to form fabric **12**. Strands **80**G may be insulating (e.g., non-conductive) strands or may be conductive strands (e.g., conductive strands **80**C may also from connecting strands **80**G connecting layers **12-1** and **12-2**, if desired).

[0082] Controller **20** may adjust the operation of one or more components of system **22** in preparation for incorporating electrical component **26** in fabric **12**. For example, controller **20** may adjust knitting equipment **22** to form regions **88** and regions **86**. In regions **88**, connecting strand **80**G travels back and forth between fabric portions **12-1** and **12-2** to form a connecting layer between outer layers **12-1** and **12-2**. In component receiving region **86**, pocket **66** may be created by deactivating one or more needles **132**. For example, in regions **88**, needles **132** may be activated and connecting strands **80**G may travel back and forth between the two needle beds. In region **86**, a subset of needles **132** may be deactivated while other needles **132** remain activated. A void such as pocket **66** may be created in region **86** where the subset of needles **132** are deactivated because connecting strands **80**G are not traveling back and forth between outer fabric layers **12-1** and **12-2** in region **86**. Meanwhile, connecting strands **80**G may travel back and forth between needle beds to form a connecting layer around (e.g., on opposing sides of) pocket **66**. When pocket **66** is formed, insertion tool **54** may insert component **26** into pocket **66** and the subset of needles **132** in region **86** may be reactivated so that strands **80**G can travel back and forth between fabric layers **12-1** and **12-2** to close pocket **66** and thereby enclose component **26** within pocket **66**. If desired, sinkers in system **22** (e.g., sinkers that would normally be used to push loops down after the loops are formed with needles **132**) may be removed or temporarily deactivated in region **86** to avoid damaging component **26** or dislodging component **26** from fabric **12**.

[0083] Component **26** may, for example, be mounted to floats of conductive strand **80**C that are floating within pocket **66** relative to one or both of outer fabric layers **12-1** and **12-2**. For example, conductive strands **80**C may have tuck stitches or knit stitches in regions **88** and may have floats in regions **86** for receiving component **26** (e.g., similar to fabric **12** of FIG. **3** which includes tuck stitches **40** in regions **88** and floats **38** in regions **86**).

[0084] If desired, component insertion tool **54** may mount component **26** to strand **80**C during loop transfer operations. In loop transfer operations, positioners **172** may raise one or more needles **132** so that the loop on those needles **132** can be transferred from a first needle bed to a second needle bed. Instead of or in addition to transferring a loop, needles **132** may be raised to deliver conductive strands **80**C to insertion tool **54**. Positioner **172** may raise a respective one of needles **132** to deliver conductive strand **80**C to insertion tool **54**. Insertion tool **54** may receive conductive strand **80**C from the raised needle **132** and may mount component **26** to conductive strand **80**C. After component **26** has been mounted to strand **80**C, the strand **80**C and component **26** may be returned to the needle **132** that delivered the component **26** to insertion tool **54**. The raised needle **132** may be dropped (or may return to loop transfer operations) and knitting may continue.

[0085] Component **26** may be mounted to outer exposed surfaces **160** of outer fabric layers **12-1** and **12-2**, may be mounted to inner hidden surfaces **162** of outer fabric layers **12-1** and **12-2**, may be mounted on connecting strands **80**G that connect outer layers **12-1** and **12-2**, and/or may be mounted to other strands **80** in fabric **12** (e.g., inlaid strands, inserted strands, braided strands, woven strands, etc.).

[0086] In the example of FIG. **9**, component **26** is mounted to strands **80**C and is located in pocket **66** between outer fabric layers **12-1** and **12-2**. Strands **80**C may be received within grooves **50** of component **26** and soldered to bond pads **40** in grooves **50** using solder **82**. Conductive strands **80**C that are coupled to component **26** may be one of connecting strands **80**G, may be strands that form part of outer fabric layers **12-1** and/or **12-2**, or may be other strands such as inlaid or inserted strands **80**.

[0087] FIG. **10** is a front view of fabric **12** showing how soldering operations may take place after component **26** is inserted within pocket **66** and/or after fabric **12** is formed. A heating tool such as heating tool **102** may be used to reflow solder **82** on component **26** to electrically couple strands **80**C to bond pads **40**. Since component **26** is hidden within fabric **12**, tool **102** may extend through openings in fabric **12** to reach component **26** inside of fabric **12**. If desired, tool **102** may be a localized heating tool that creates localized heat such as a spark (e.g., using reactive films and/or other localized heating techniques) to reflow solder **82** without overheating component **26** and/or fabric **12**.

[0088] FIG. **11** is a top view of fabric **12** showing how connecting strands **80**G may form a connecting layer **106** between outer fabric layers **12-1** and **12-2**. Connecting strand **80**G may be formed from conductive strand **80**C. Connecting layer **106** may be formed entirely from conductive strands **80**C or may only be formed from conductive strands **80**C in regions **86** where component **26** is received.

[0089] If desired, grooves on component **26** may be shaped to receive knit strands **80**C in connecting layer **106**. As shown in FIG. **12**, for example, grooves **50** may have sloped sidewalls **104** for receiving conductive strands **80** of connecting layer **106**. Grooves **50** may be plated through-holes and/or may have other conductive materials for electrically coupling component **26** to strands **80**C. Sloped sidewalls **104** may accommodate machine tolerances while also allowing space for solder to enter into grooves **50**.

[0090] In the example of FIG. **13**, component **26** has first and second portions that join together around conductive strands **80**C. Component **26** may include first portion **26**A and second portion **26**B. Portions **26**A and **26**B may have mating grooves such as grooves **50**A and grooves **50**B. Portions **26**A and **26**B may attach to one another using attachment structures **194** such as snaps, clips, magnets, hook and loop fasteners, adhesive, screws, and/or other attachment structures.

[0091] During knitting operations, insertion tool **54** may insert first portion **26**A of component **26** into fabric **12** (e.g., onto the surface of a single layer of weft knit fabric of the type shown in FIG. **3** or in pocket **66** of a double knit fabric of the type shown in FIG. **9**). Knitting system **22** may then knit conductive strands **80**C over first portion **26**A. After conductive strands **80**C are knitted over first portion **26**A, insertion tool **54** may insert second portion **26**B of component **26** and may attach second portion **26**B to first portion **26**A to trap conductive strands **80**C within grooves **50**A and **50**B of component **26**.

[0092] In the example of FIG. **14**, component **26** has one or more through holes that are configured to receive a respective one of loops **24**. During knitting, system **22** may knit strands **80** to create courses **42**. Each course **42** includes a row of loops **24**. Some of courses **42** (or one or more portions of a given course **42**) may be formed from conductive strands **80**C and may include one or more conductive loops such as conductive loop **24**C.

[0093] Knitting system **22** may create conductive loop **24**C with extra length. Insertion tool **54** may place component **26** on the larger loop **24**C and loop **24**C may be pulled through an opening in component **26** such as opening **150**. Component **26** may be electrically connected to loop **24**C. For example, component **26** may include electrodes **152** (e.g., an anode and a cathode) that are electrically connected to conductive loop **24**C using solder or other conductive material. Electrodes **152** may partially or completely cover the walls of opening **150** in component **26** to form bond pads with which component **26** may be electrically coupled to strand **80**C.

[0094] If desired, loop **24**C may be cut in location **108** to isolate the electrical connection between the terminals of component **26**. The conductive loop segment **24**C-**1** on one side of cut location **108** may be coupled to cathode **152** on component **26** and conductive loop segment **24**C-**2** on the opposing side of cut location **108** may be coupled to anode **152** on component **26**.

[0095] Component attachment schemes of the type shown in FIG. **14** may be incorporated into any suitable fabric **12** such as fabric **12** of FIGS. **1-4** and **9-11**.

[0096] FIGS. **15** and **16** show an illustrative circular knit fabric that may incorporate electrical components **26**. In the example of FIG. **16**, fabric **12** has been formed using a circular knitting machine to form a continuous loop of fabric that wraps around longitudinal axis **94**. Fabric **12** may include one or more conductive strands **80**C that spiral continuously around longitudinal axis **94**. Conductive strand **80**C may, for example, be a single continuous strand that spirals around longitudinal axis **94**. Conductive strand **80**C may be an inlaid strand, a knit strand formed from all knit stitches, a knit strand having knit stitches, tuck stitches, and/or floats, and/or other suitable strand **80** in fabric **12**.

[0097] Following formation of fabric **12** of FIG. **15**, post-processing operations may take place to form circuits using conductive strands **80**C in fabric **12**. As shown in FIG. **16**, for example, conductive strand **80**C may be cut in select locations and joined together in other select locations. Electrical connections **92** between pairs of segments of conductive strand **80**C may be formed by welding, crimping, soldering, conductive adhesive such as anisotropic conductive film and other conductive adhesive, non-conductive adhesive, electroplating, and/or other techniques for making electrical connections between segments of conductive strands **80**C. Gaps **90** between segments of conductive strands **80**C may be formed by cutting, ablating, or otherwise removing portions of conductive strands **80**C to form pairs of electrically isolated segments.

[0098] If desired, one or more electrical components **26** (e.g., components of the type described in connection with FIGS. **1-14**) may be incorporated into the circular knit fabric of FIG. **16** using any of the component insertion techniques described in connection with FIGS. **1-14**.

[0099] The foregoing is merely illustrative and various modifications can be made by those skilled in the art without departing from the scope and spirit of the described embodiments. The foregoing embodiments may be implemented individually or in any combination.

What is claimed is:

1. A weft knit fabric, comprising:

non-conductive strands that form an outer weft knit layer;

a conductive strand interlaced with the non-conductive strands, wherein the conductive strand comprises a float between first and second stitches; and

an electrical component mounted to the float and electrically coupled to the conductive strand.

2. The weft knit fabric defined in claim **1** wherein the first and second stitches comprise tuck stitches.

3. The weft knit fabric defined in claim **1** wherein the first and second stitches comprise knit stitches.

4. The weft knit fabric defined in claim **1** wherein the float passes over at least two loops in the outer weft knit layer.

5. The weft knit fabric defined in claim **1** further comprising an additional outer weft knit layer interlaced with the outer weft knit layer, wherein the electrical component is interposed between the outer weft knit layer and the additional outer weft knit layer.

6. The weft knit fabric defined in claim **5** further comprising connecting strands that travel back and forth between the outer weft knit layer and the additional outer weft knit layer.

7. The weft knit fabric defined in claim **6** further comprising a pocket formed between the outer weft knit layer and the additional outer weft knit layer.

8. The weft knit fabric defined in claim **7** wherein the connecting strands are located on opposing sides of the pocket.

9. The weft knit fabric defined in claim **1** wherein the electrical component has first and second portions and wherein the conductive strand is interposed between the first and second portions.

10. The weft knit fabric defined in claim **9** wherein the first and second portions are coupled together using attachment structures selected from the group consisting of: snaps, clips, adhesive, magnets, and screws.

11. A weft knit fabric, comprising:

first and second outer weft knit layers;

a conductive strand that travels back and forth between the first and second outer weft knit layers; and

an electrical component mounted to the conductive strand and interposed between the first and second outer weft knit layers.

12. The weft knit fabric defined in claim **11** wherein the electrical component comprises a plated through-hole that receives the conductive strand.

13. The weft knit fabric defined in claim **12** wherein the plated through-hole has sloped sides.

14. The weft knit fabric defined in claim **11** wherein the first and second outer weft knit layers comprise non-conductive strands.

15. The weft knit fabric defined in claim **11** wherein the electrical component has first and second portions and attachment structures that attach the first portion to the second portion, wherein the attachment structures are selected from the group consisting of: snaps, clips, adhesive, magnets, and screws.

16. A weft knit fabric, comprising:

strands that form courses of loops, wherein the strands comprise a conductive strand that forms a conductive loop in the courses of loops; and

an electrical component having a through-hole that receives the conductive loop, wherein the conductive loop has first and second conductive loop segments that are electrically isolated from one another and wherein the electrical component has a first electrode coupled to the first conductive loop segment and a second electrode coupled to the second conductive loop segment.

17. The weft knit fabric defined in claim **16** wherein the weft knit fabric comprises a circular knit fabric.

18. The weft knit fabric defined in claim **17** wherein the circular knit fabric loops around a longitudinal axis and wherein the conductive strand spirals at least partially around the longitudinal axis.

19. The weft knit fabric defined in claim **18** wherein the conductive strand has a first pair of segments that are joined by an electrical connection and a second pair of segments that are electrically isolated from one another.

20. The weft knit fabric defined in claim **16** wherein the weft knit fabric comprises a double knit fabric having first and second weft knit layers.

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