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(54) **FABRIC STRAPS FOR ELECTRONIC DEVICES**

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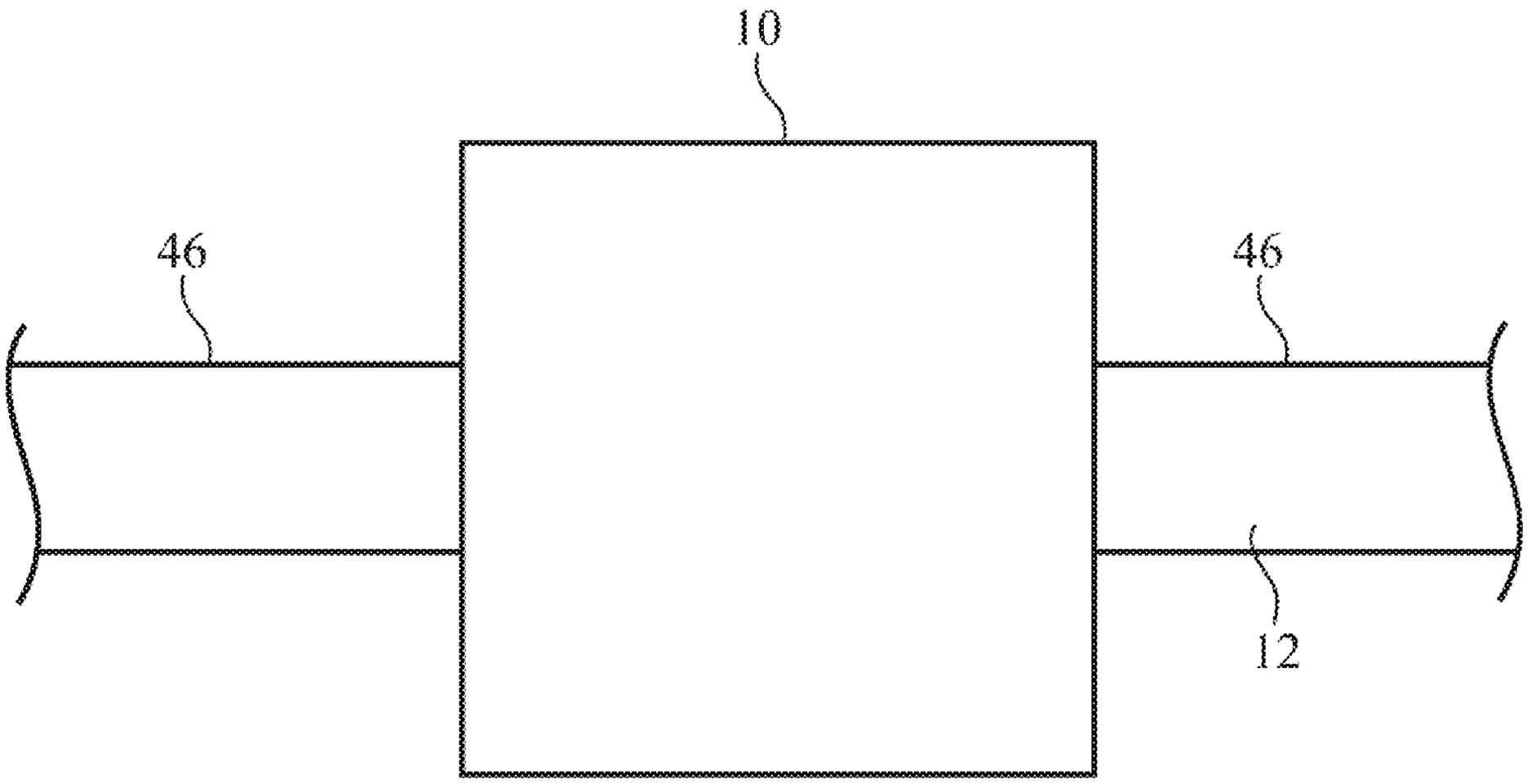
(57) **ABSTRACT**

A fabric strap may be used to attach a wearable electronic device to a user's body. The fabric strap may include a stretchable inner fabric layer formed from mesh fabric. A first set of ribs may be formed on a first side of the inner fabric layer and a second set of ribs may be formed on a second opposing side of the inner fabric layer. Load-modifying structures may be located in the ribs and may be used to increase the initial force required to stretch the strap, while allowing additional elongation to occur without requiring increasing force once a certain elongation percentage is reached. The load-modifying structures may be located in upper portions of the ribs and/or may span across openings in the ribs, and may include stitching, stiffeners, fabric layers, metal or plastic materials, spring members, and/or other structures.



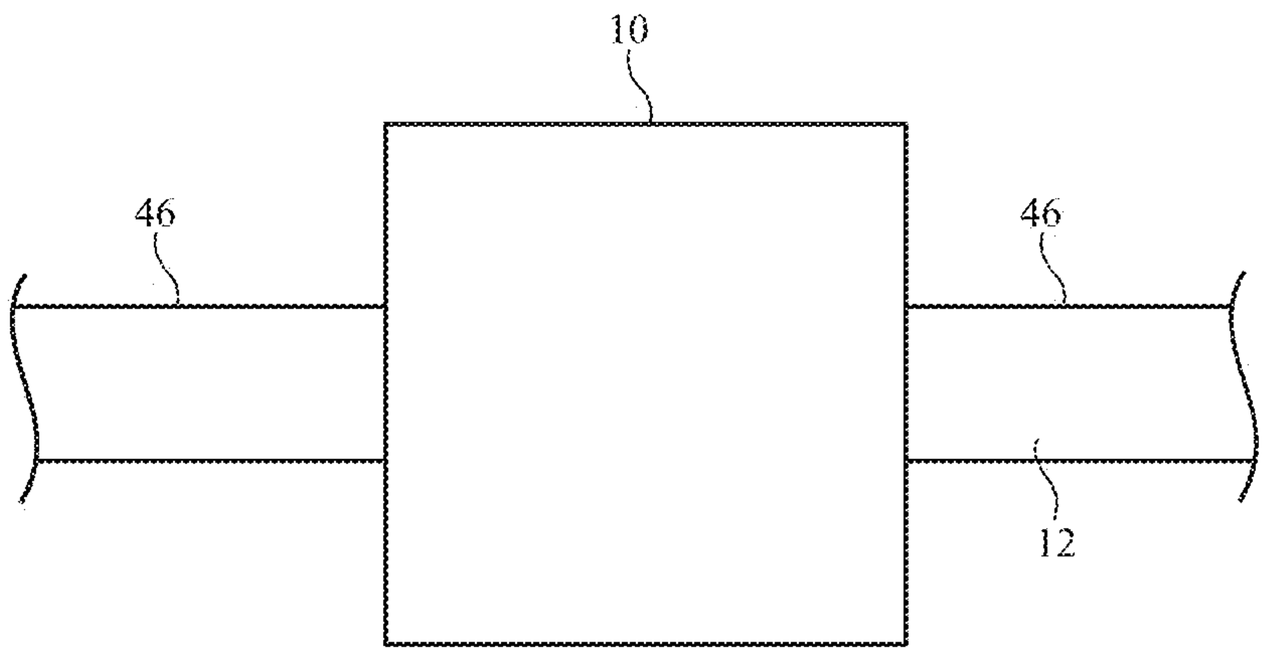


FIG. 1

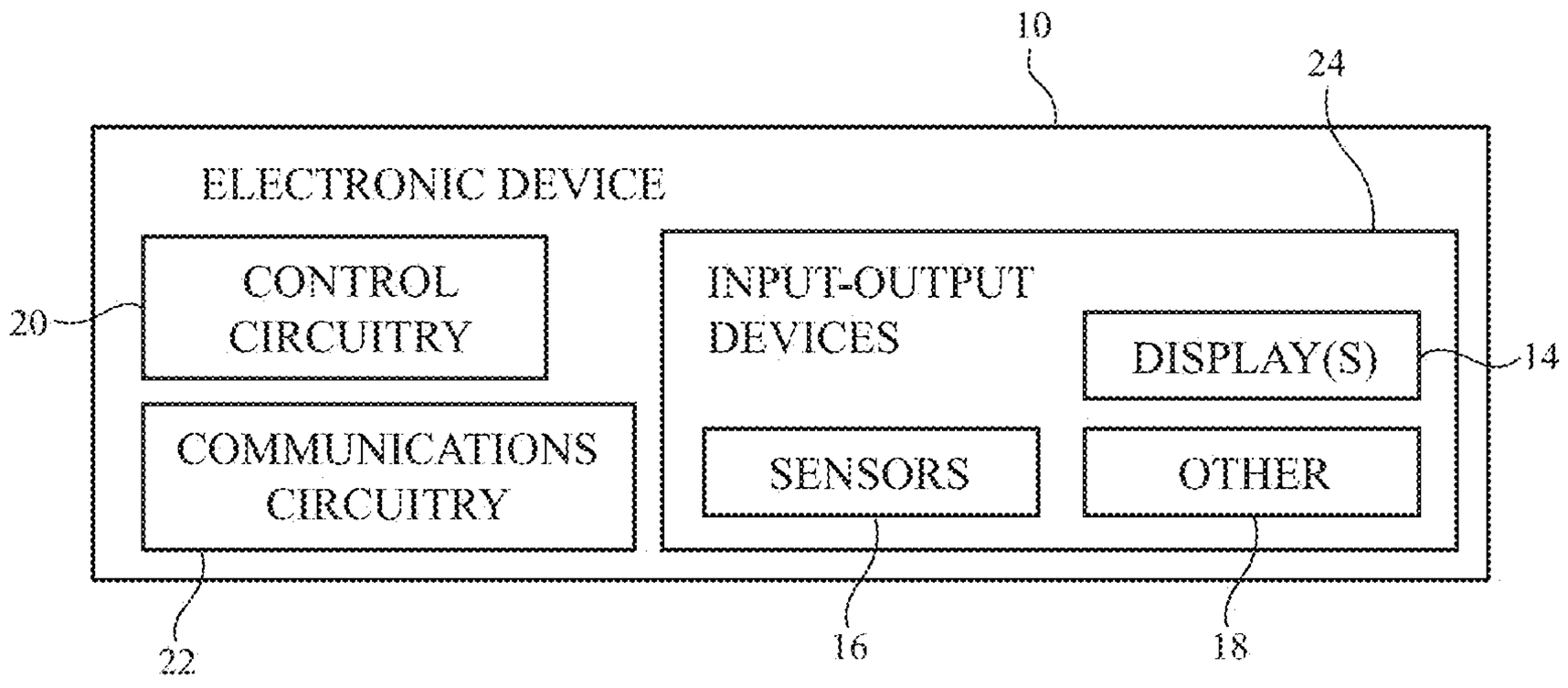

10
24
ELECTRONIC DEVICE
20
CONTROL CIRCUITRY
INPUT-OUTPUT DEVICES
DISPLAY(S)
14
COMMUNICATIONS CIRCUITRY
SENSORS
OTHER
22
16
18

FIG. 2

64
STRAND SOURCE
66
68
GUIDE BARS
AND NEEDLES
70
12
TAKE DOWN
74

FIG. 3

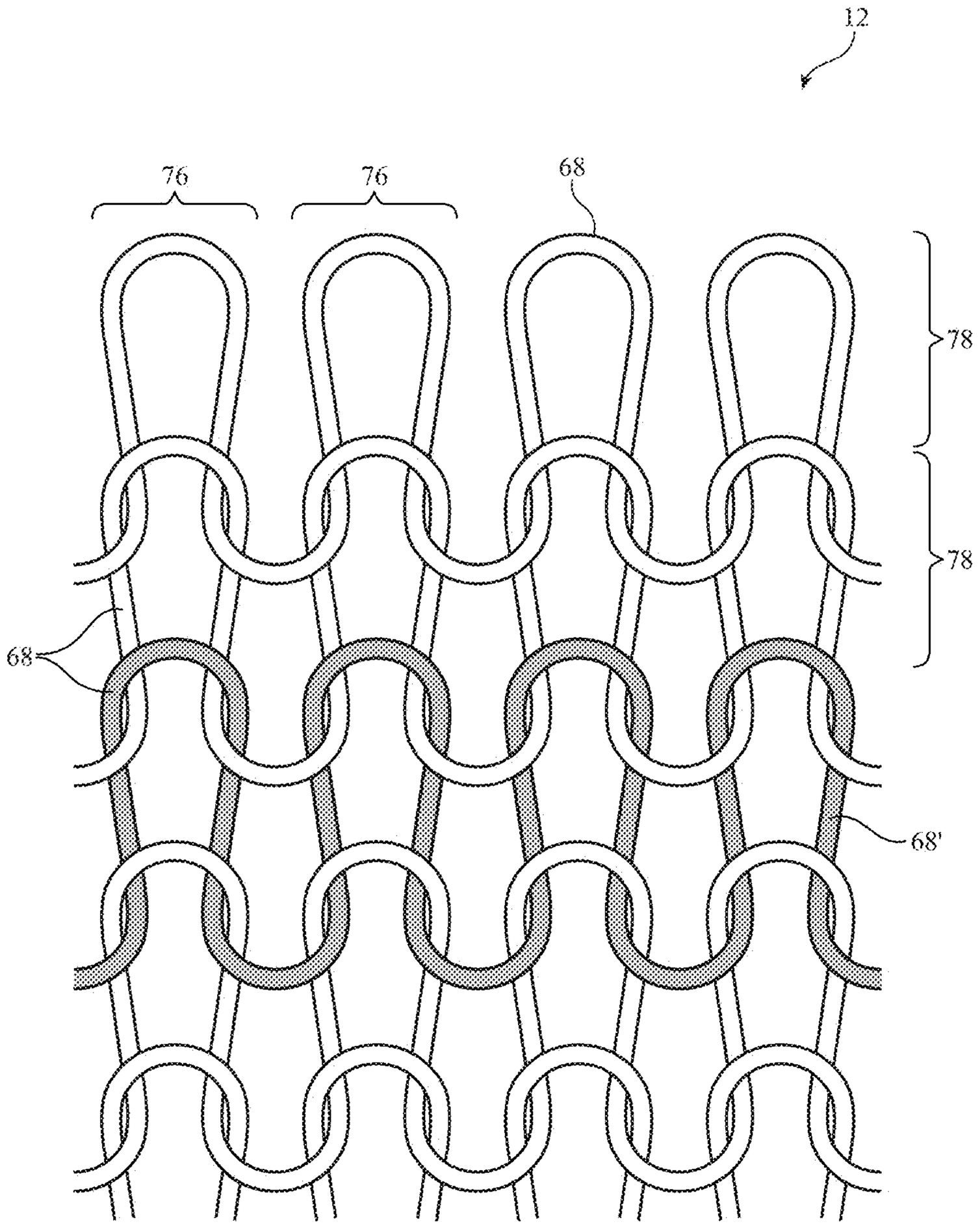


FIG. 4

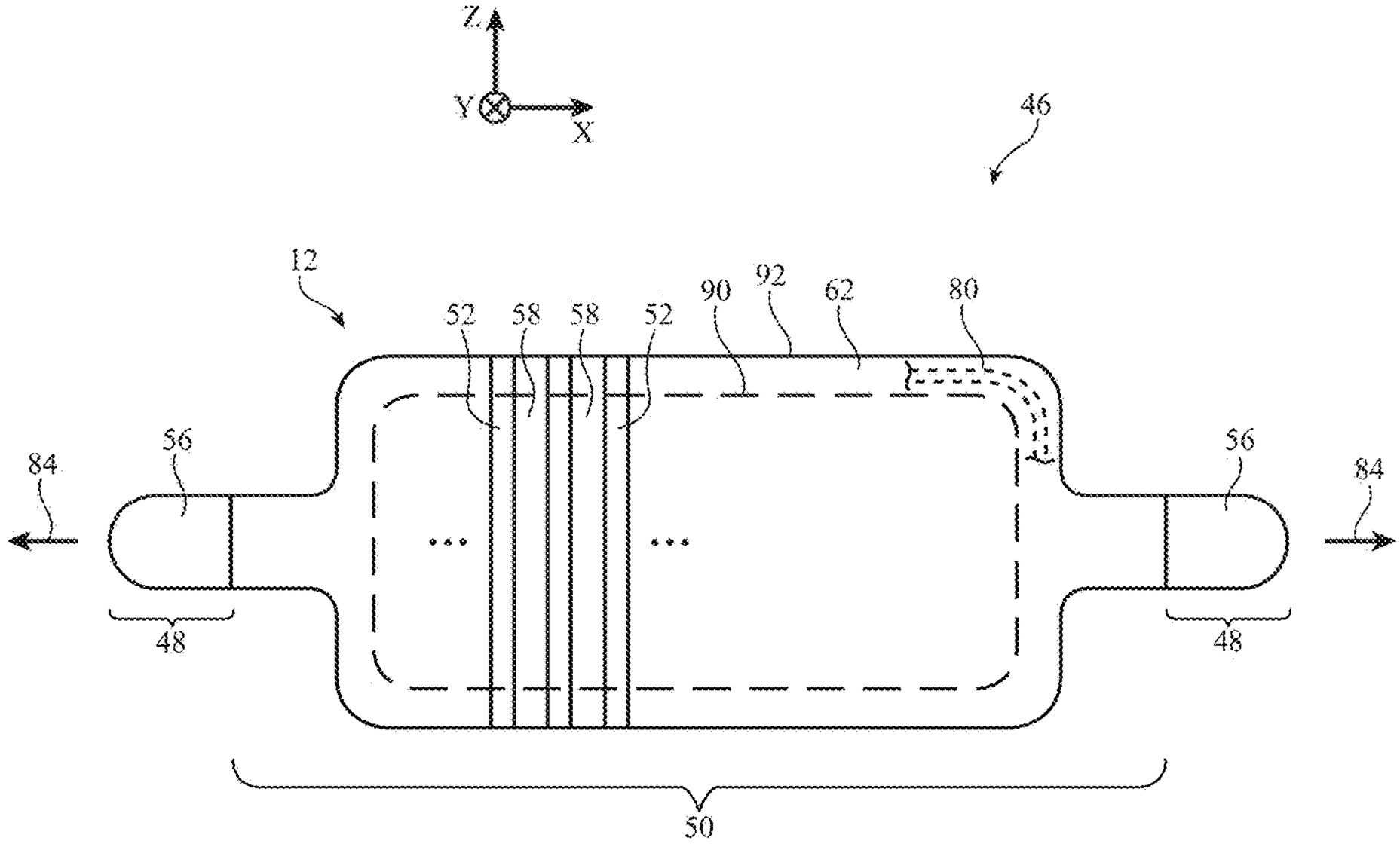


FIG. 5

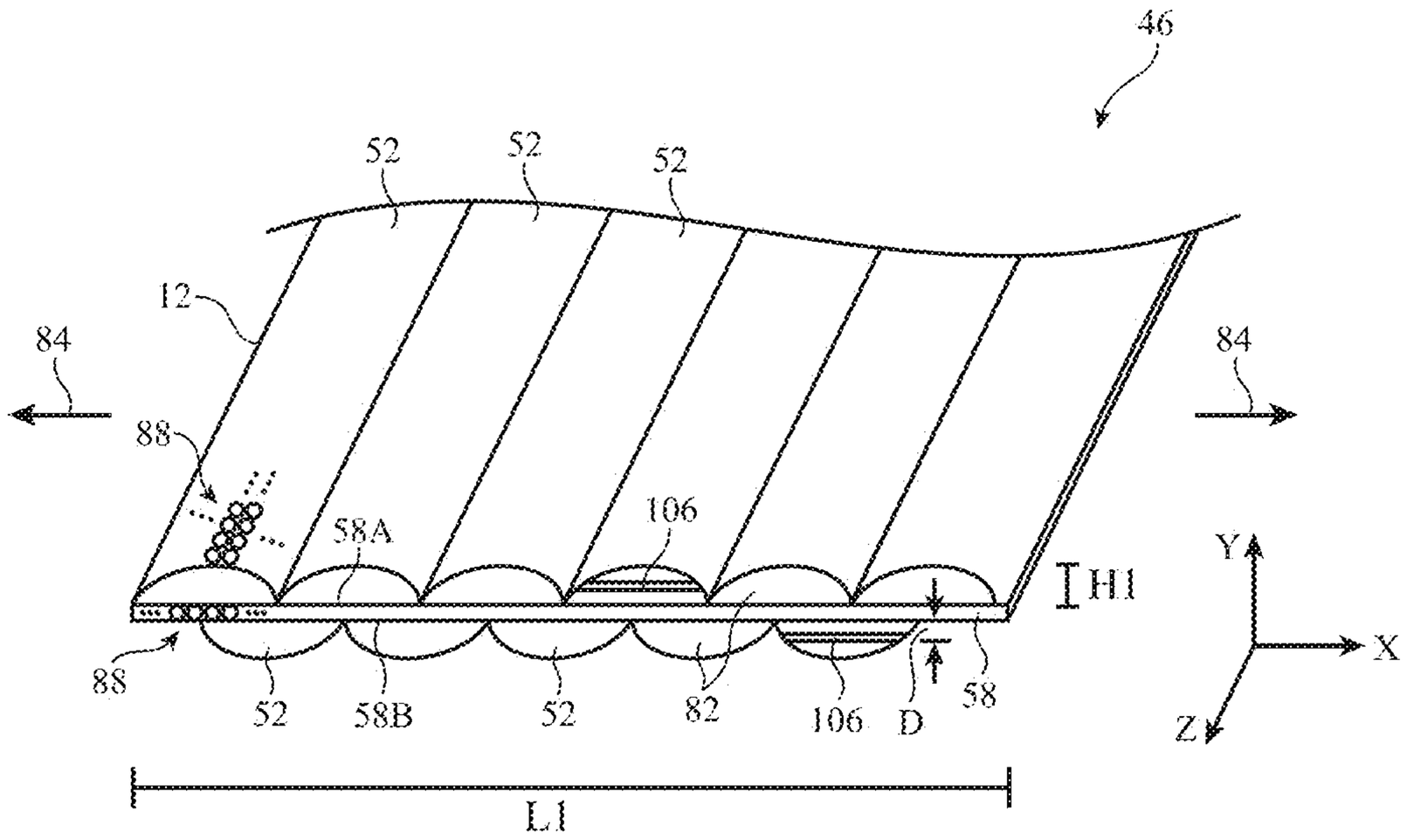

46
52
52
52
12
84
84
88
58A
106
H1
Y
X
Z
88
52
58B
52
82
106
D
58
L1

FIG. 6

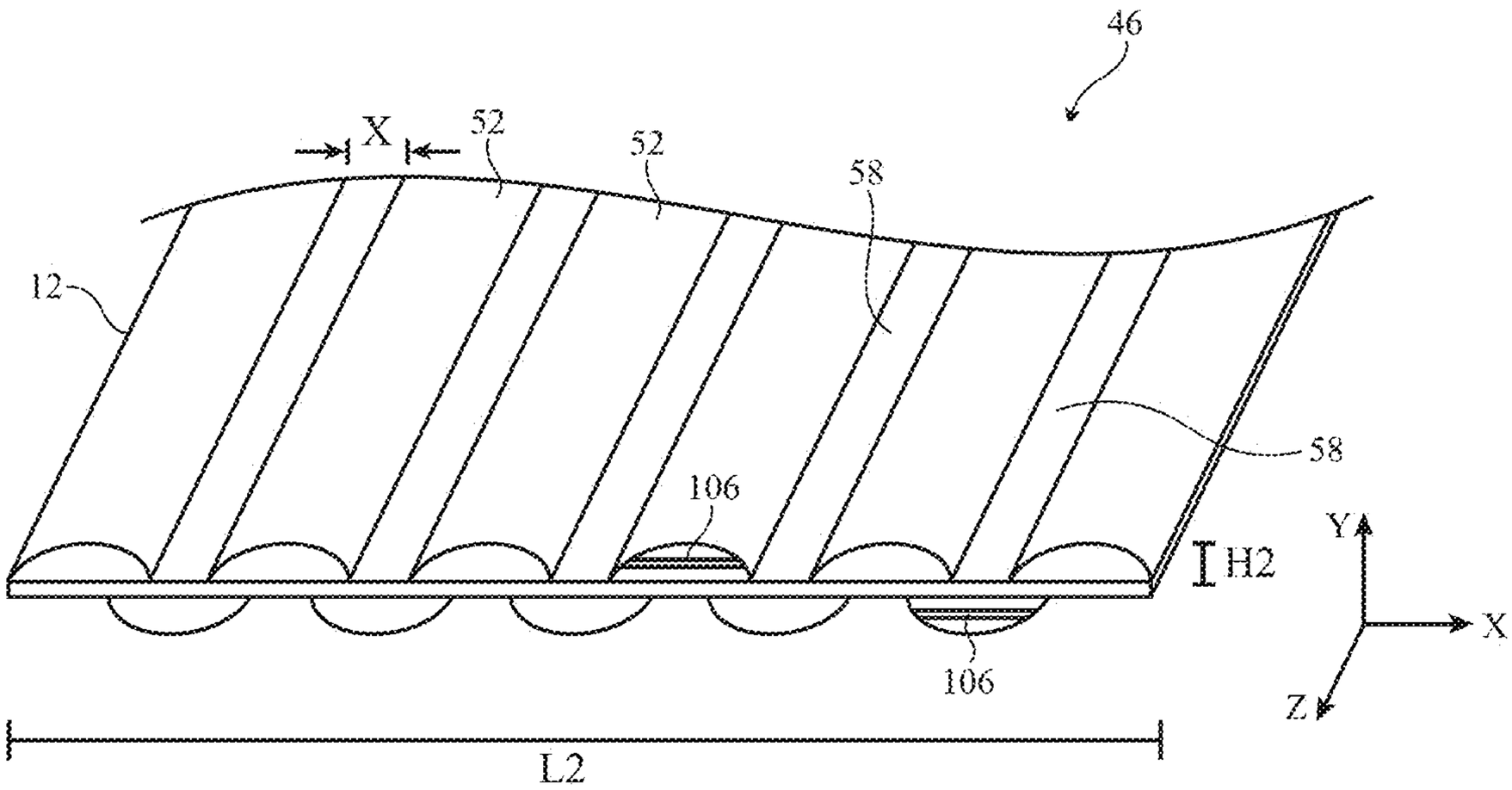

46
X
52
52
58
12
58
106
H2
Y
X
Z
106
L2

FIG. 7

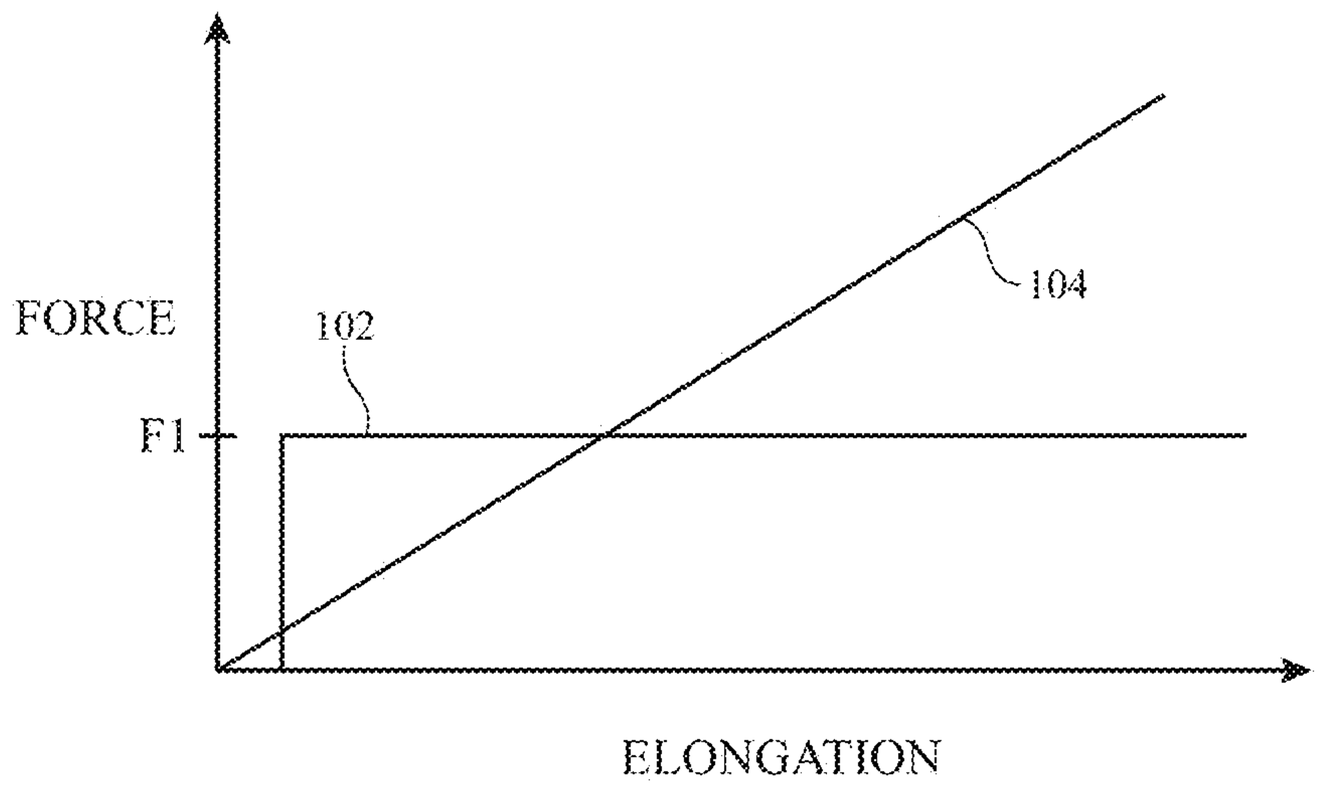


FIG. 8

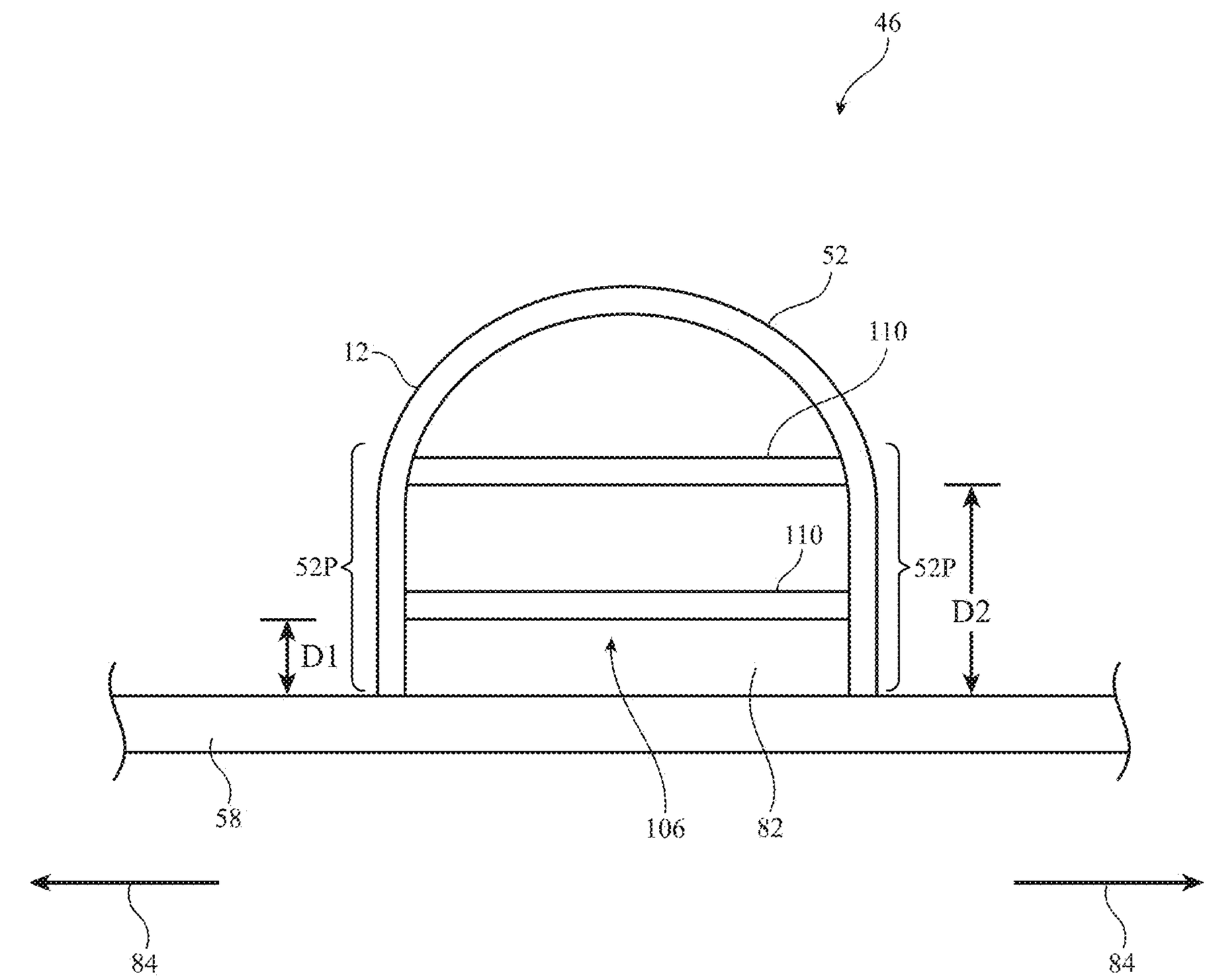


FIG. 9

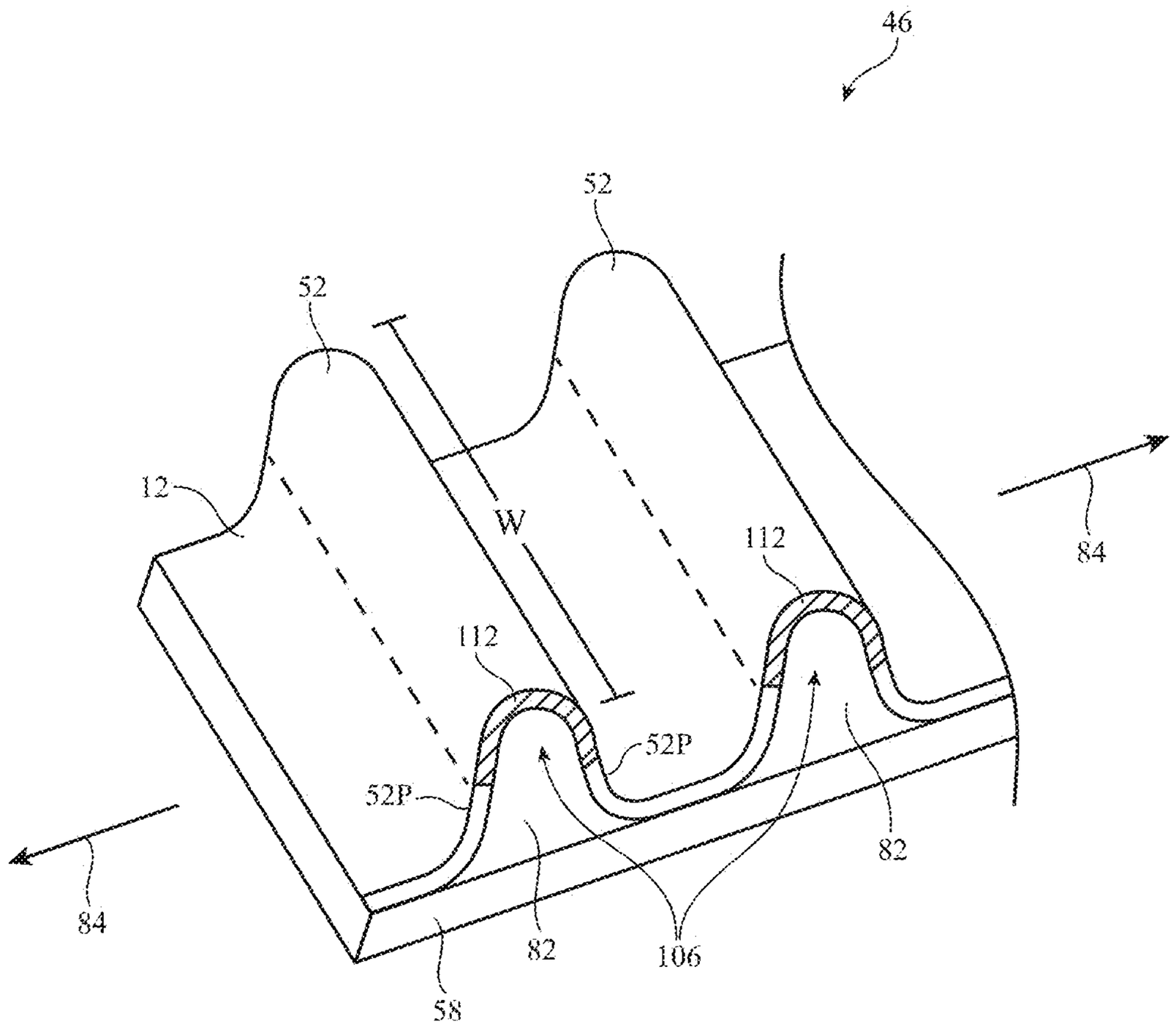


FIG. 10

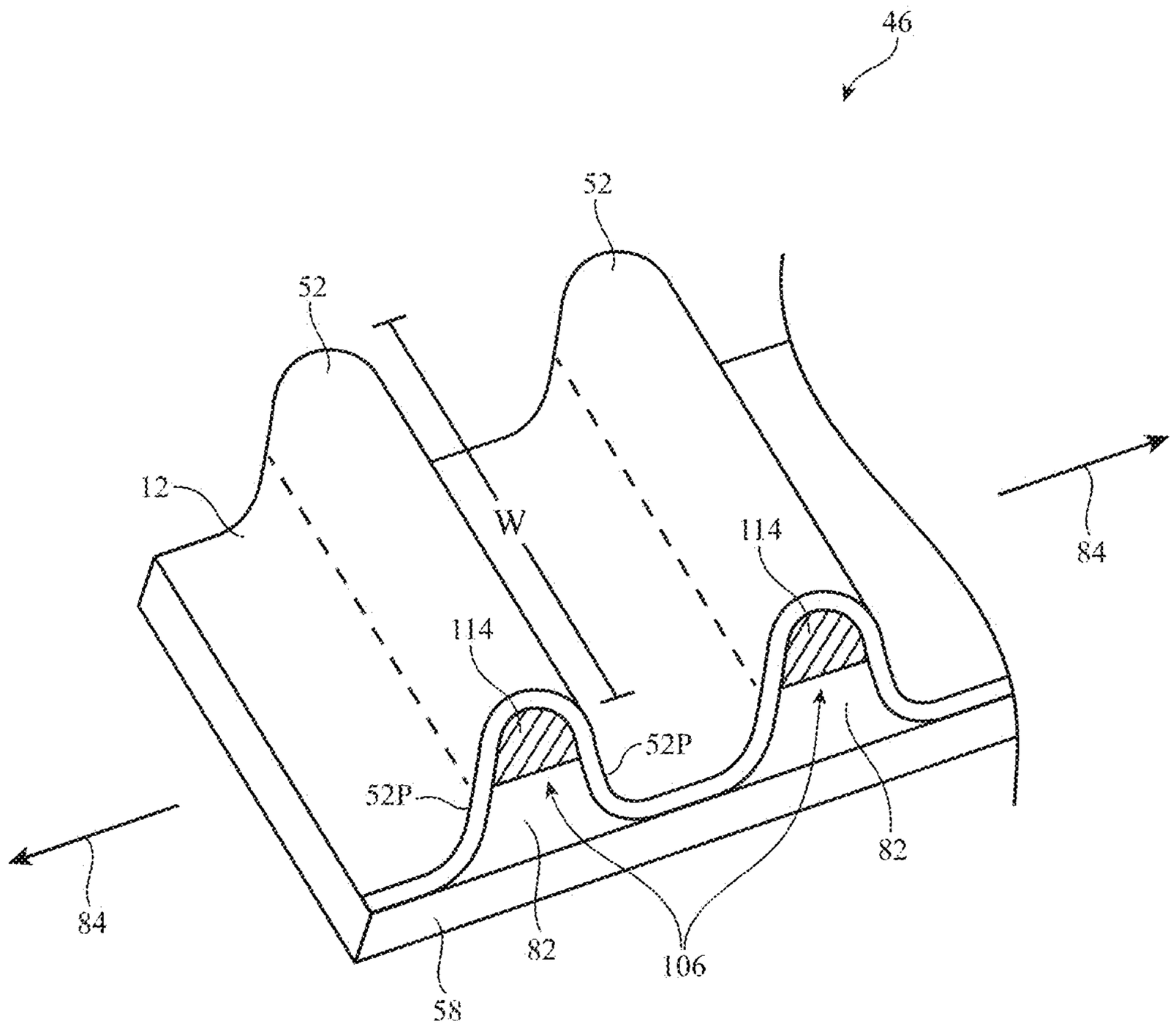


FIG. 11

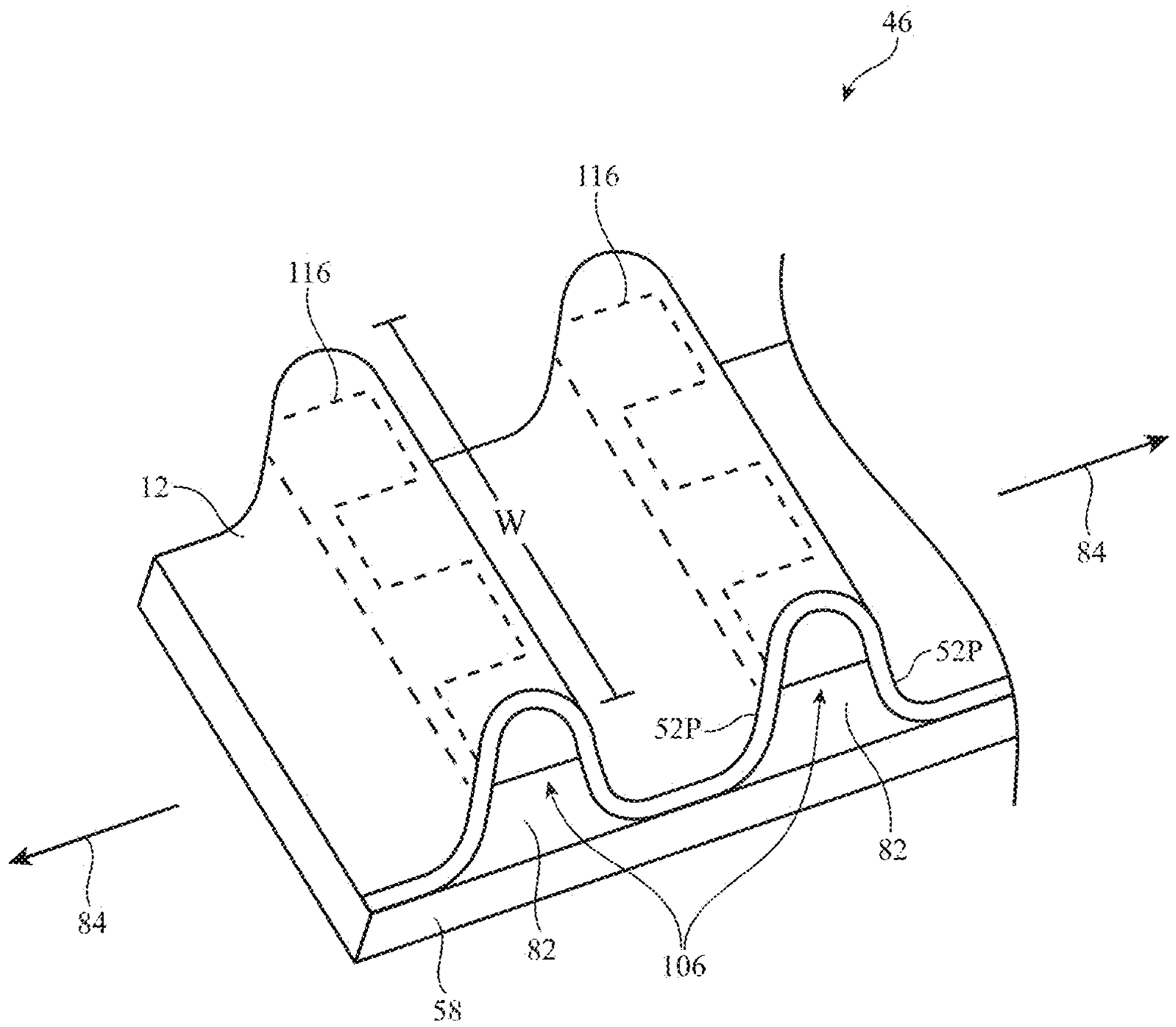


FIG. 12

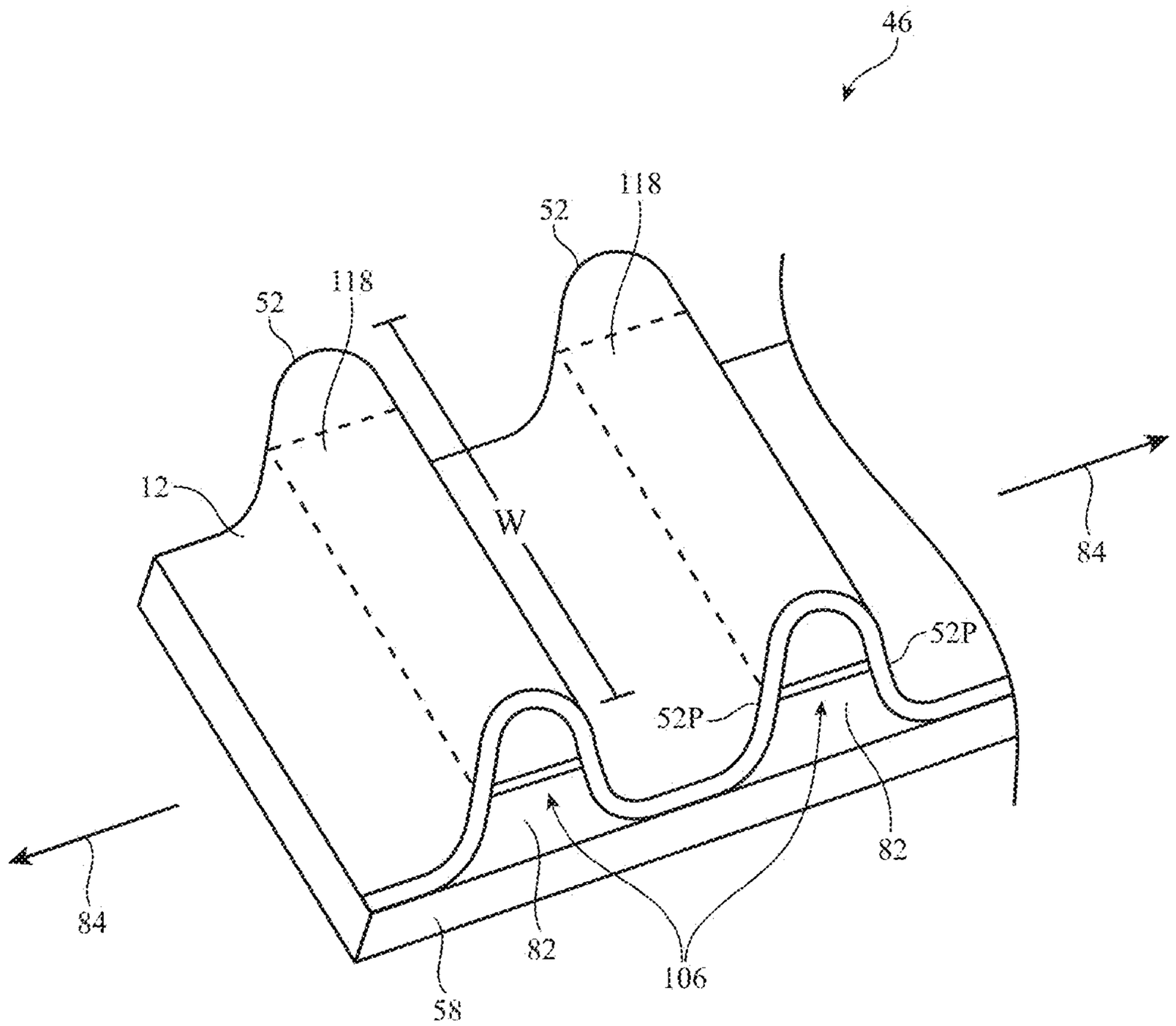


FIG. 13

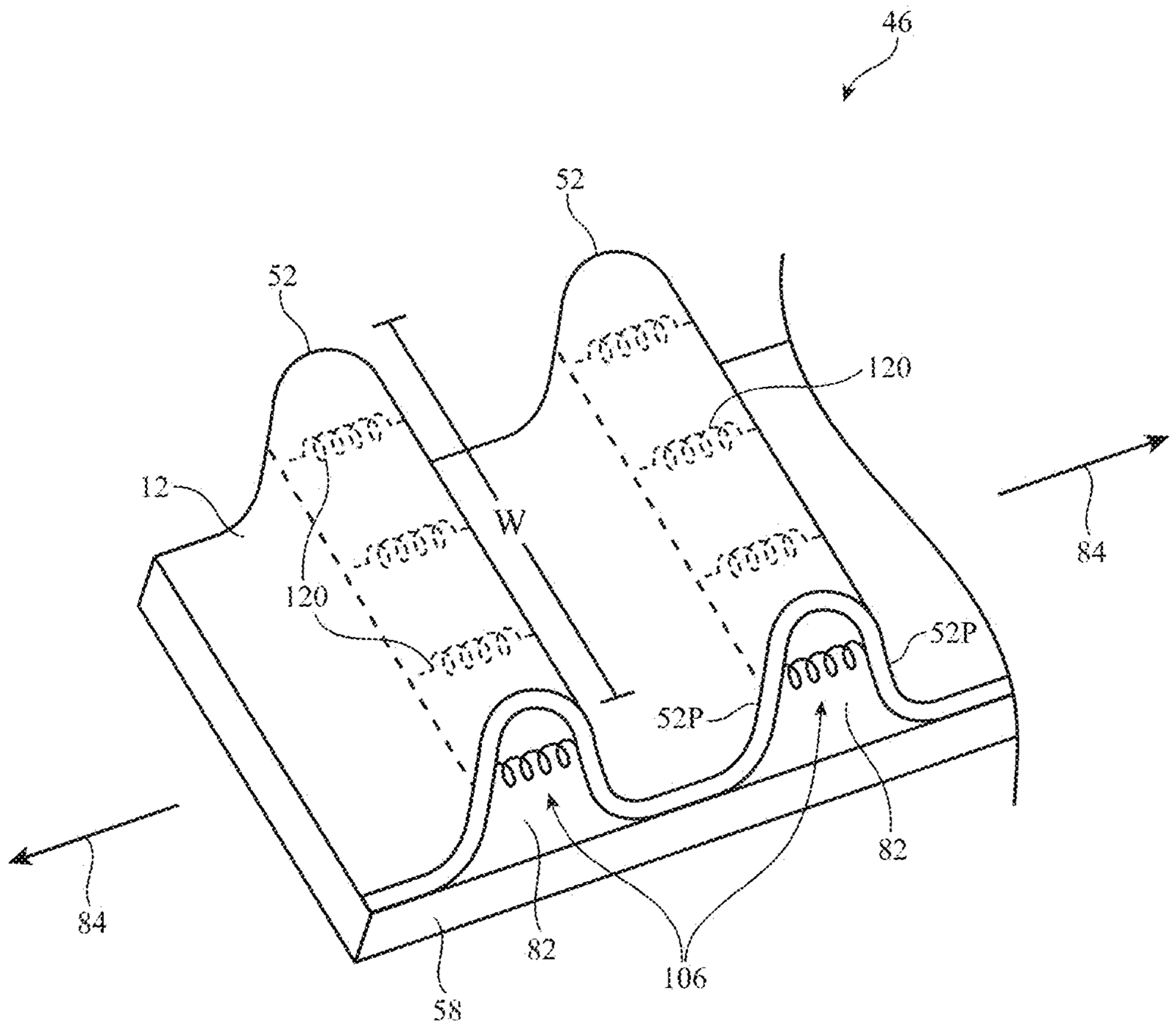


FIG. 14

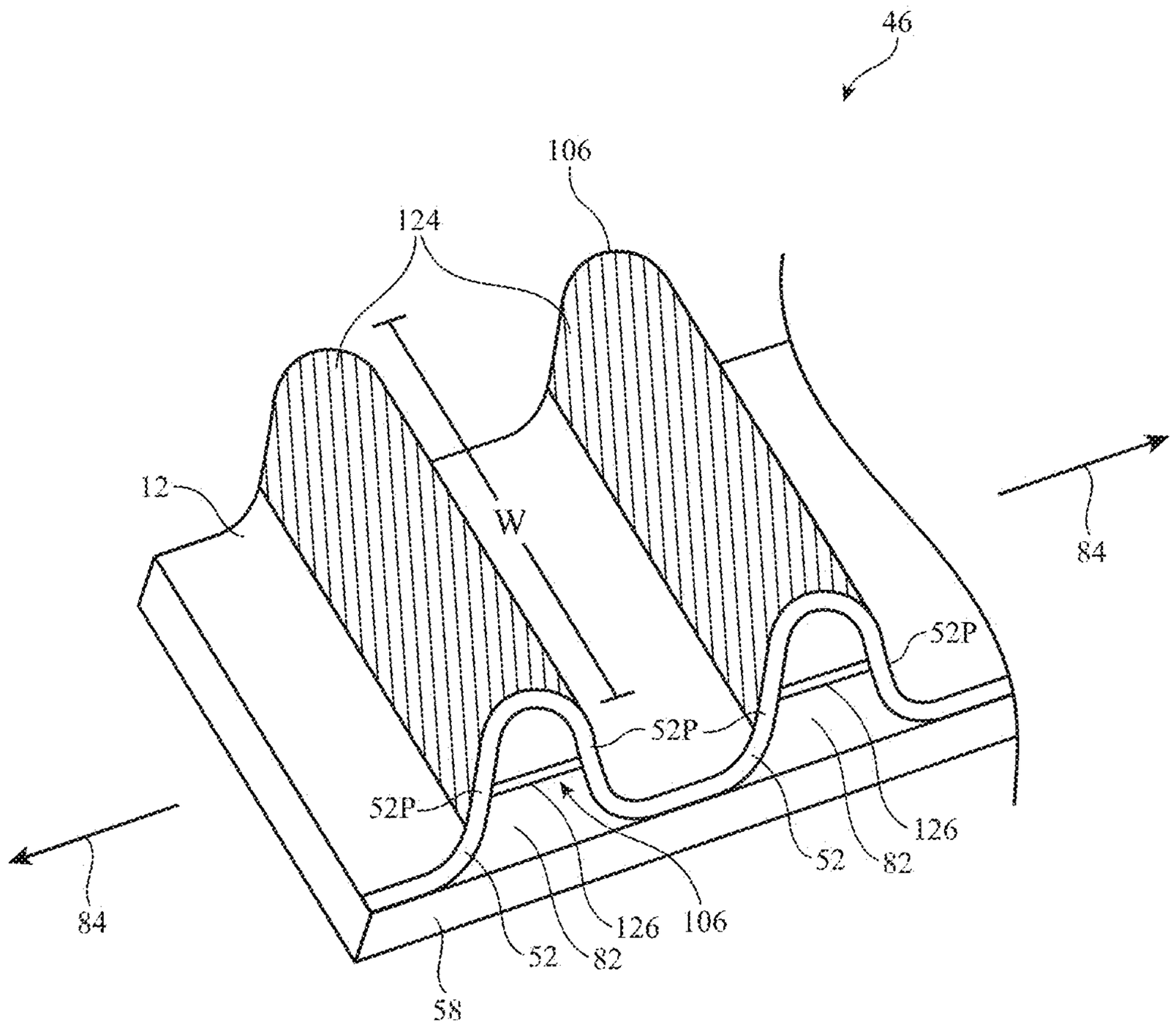


FIG. 15

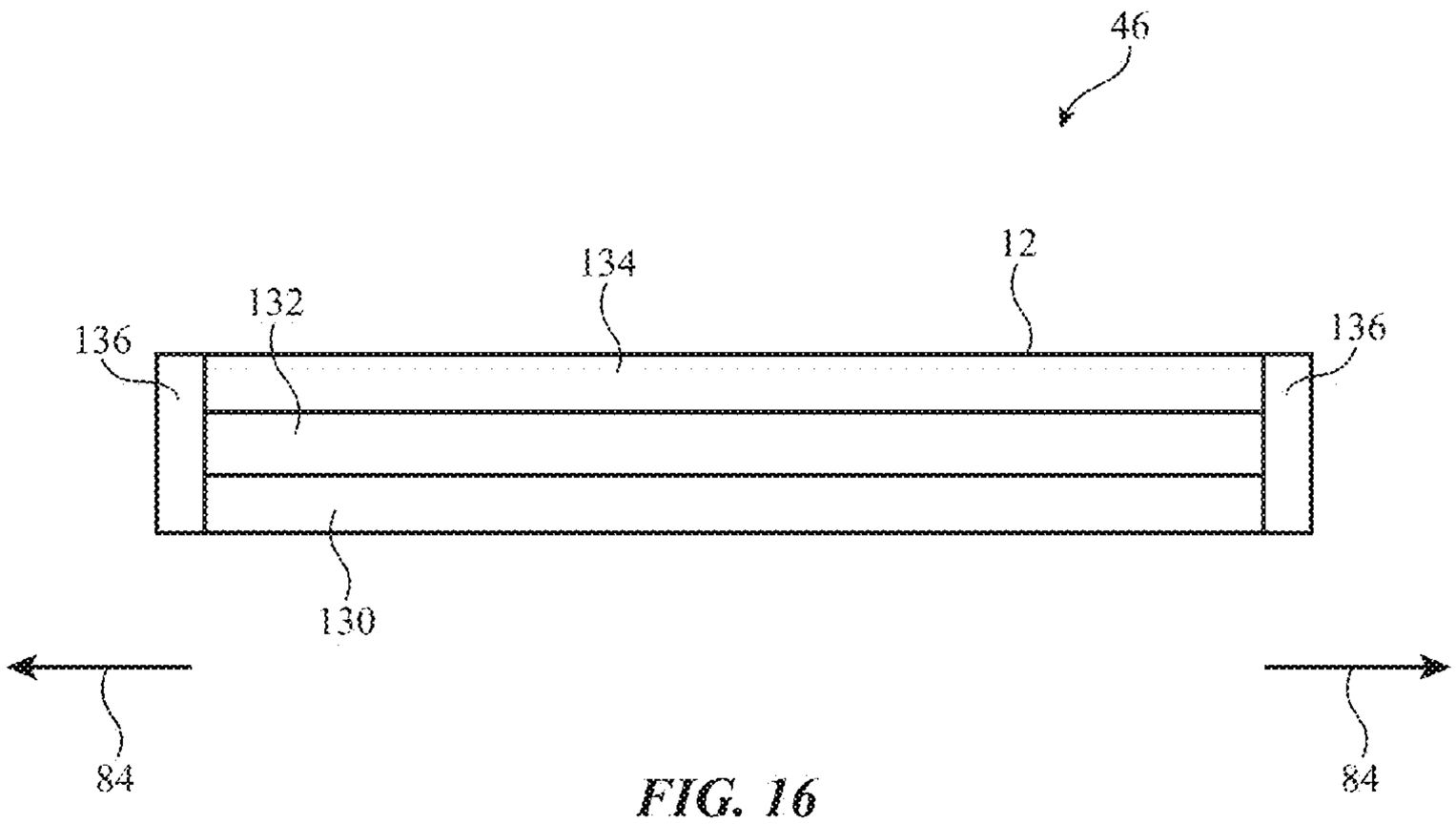


FIG. 16

FABRIC STRAPS FOR ELECTRONIC DEVICES

[0001] This application claims the benefit of U.S. provisional patent application No. 63/512,047, filed Jul. 5, 2023, which is hereby incorporated by reference herein in its entirety.

FIELD

[0002] This relates generally to fabric straps and, more particularly, to fabric straps for wearable electronic devices.

BACKGROUND

[0003] Fabric straps may be used to attach wearable electronic devices to the body of a user. For example, a fabric head strap may be used to attach a head-mounted device to a user's head. A fabric wrist band may be used to attach a watch to a user's wrist. Conventional fabric bands for wearable devices can be uncomfortable and cumbersome to wear.

SUMMARY

[0004] A fabric strap may be used to attach a wearable electronic device to a user's body. For example, a fabric head strap may be used to attach a head-mounted device to a user's head, a fabric wrist strap may be used to attach a wristwatch to a user's wrist, and/or fabric straps may be used to attach other types of electronic devices to a user's body.
[0005] The fabric strap may include a stretchable inner fabric layer formed from mesh fabric. A first set of ribs may be formed on a first side of the inner fabric layer and a second set of ribs may be formed on a second opposing side of the inner fabric layer. Load-modifying structures may be located in the ribs and may be used to increase the initial force required to stretch the strap, while allowing additional elongation to occur without requiring increasing force once a certain elongation percentage is reached.
[0006] The load-modifying structures may be located in upper portions of the ribs and/or may span across openings in the ribs, and may include stitching, stiffeners, fabric layers, metal or plastic materials, spring members, and/or other structures. The load-modifying structures may allow the fabric strap to accommodate a larger range of diameters without applying excessive force during wear.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. **1** is a top view of an illustrative wearable electronic device having a strap in accordance with an embodiment.
[0008] FIG. **2** is a schematic diagram of an illustrative wearable electronic device in accordance with an embodiment.
[0009] FIG. **3** is a schematic diagram of an illustrative knitting system in accordance with an embodiment.
[0010] FIG. **4** is a front view of an illustrative layer of knit fabric in accordance with an embodiment.
[0011] FIG. **5** is a front view of an illustrative fabric strap in accordance with an embodiment.
[0012] FIG. **6** is a perspective view of an illustrative fabric strap in an unstretched state in accordance with an embodiment.
[0013] FIG. **7** is a perspective view of an illustrative fabric strap in a stretched state in accordance with an embodiment.
[0014] FIG. **8** is a graph showing illustrative force-to-elongation curves for a fabric strap in accordance with an embodiment.
[0015] FIG. **9** is a side view of an illustrative fabric strap having ribs with load-modifying structures in accordance with an embodiment.
[0016] FIG. **10** is a perspective view of an illustrative fabric strap having ribs with load-modifying structures on the ribs in accordance with an embodiment.
[0017] FIG. **11** is a perspective view of an illustrative fabric strap having ribs with load-modifying structures that at least partially fill openings in the ribs in accordance with an embodiment.
[0018] FIG. **12** is a perspective view of an illustrative fabric strap having ribs with load-modifying structures formed from stitches that span across openings in the ribs in accordance with an embodiment.
[0019] FIG. **13** is a perspective view of an illustrative fabric strap having ribs with load-modifying structures such as flat strips of material that span across openings in the ribs in accordance with an embodiment.
[0020] FIG. **14** is a perspective view of an illustrative fabric strap having ribs with load-modifying structures formed from springs that span across openings in the ribs in accordance with an embodiment.
[0021] FIG. **15** is a perspective view of an illustrative fabric strap having ribs with load-modifying structures formed from a first material in an upper portion of the ribs and a second material spanning across openings in the ribs in accordance with an embodiment.
[0022] FIG. **16** is a side view of an illustrative fabric strap having a flexible layer and a stiffener separated by a compressible layer in accordance with an embodiment.

DETAILED DESCRIPTION

[0023] Electronic devices such as wearable electronic devices may be provided with fabric. Fabric may be used to form a strap, band, or other attachment structure that attaches the wearable electronic device to a user's body. For example, a fabric head strap may attach a head-mounted device to a user's head. A fabric wrist strap may attach a wristwatch to a user's wrist. The fabric may be knit fabric, woven fabric, braided fabric, and/or any other suitable type of fabric. Illustrative configurations in which fabric straps are used for head-mounted devices, wristwatch devices, fitness bands, and/or other wearable electronic devices may sometimes be described herein as an example. In general, any suitable portable electronic device may be provided with a strap and the strap may be formed from any suitable fabric material. The straps or other fabric structures may be used to attach the portable electronic device to an arm, leg, head, torso, wrist, or other portion of a user's body.
[0024] A fabric strap may include a stretchable inner layer such as a mesh fabric layer. First and second sets of ribs may be formed on respective first and second opposing sides of the stretchable inner layer. The ribs may provide cushion against the user's body (e.g., wrist, head, etc.) while also allowing airflow through the fabric strap. Load-modifying structures may be incorporated into the ribs to alter the force-to-elongation characteristics of the fabric strap. The load-modifying structures may allow the fabric strap to accommodate a wider range of sizes without applying excessive force during wear. The load-modifying structures may serve as parallel springs within the ribs that are parallel

to the stretchable inner layer and that are initially separated from the stretchable inner layer by a distance when the strap is in an unstretched state. As the stretchable inner layer is elongated, the distance between the load-modifying structures and the stretchable inner layer reduces, thereby allowing additional elongation to occur without requiring excessive force. The fabric strap can therefore accommodate a wider range of wrist sizes and/or head sizes while remaining comfortable during wear.

[0025] A top view of an illustrative wearable electronic device that may include a fabric strap is shown in FIG. **1**. As shown in FIG. **1**, wearable electronic devices such as electronic device **10** may include one or more straps such as strap **46**. In some configurations, device **10** may be a head-mounted device. For example, device **10** may include head-mounted support structures that help support device **10** on a user's head. The head-mounted support structures may support electronic components such as displays, integrated circuits, actuators, batteries, sensors, and/or other circuits and structures for device **10**. The head-mounted support structures may form glasses, a hat, a helmet, goggles, and/or other head-mounted device.

[0026] Device **10** may have left and right optical modules. Each optical module may include a respective display, lens, and support structure such as a lens barrel. For example, a left lens barrel may support a left display and a left lens, and a right lens barrel may support a right display and a right lens. The displays may include arrays of pixels or other display devices to produce images. For example, the displays may include organic light-emitting diode pixels formed on substrates with thin-film circuitry and/or formed on semiconductor substrates, pixels formed from crystalline semiconductor dies, liquid crystal display pixels, scanning display devices, and/or other display devices for producing images. Lenses may include one or more lens elements for providing image light from the displays to respective eyes boxes. Lenses may be implemented using refractive glass lens elements, using mirror lens structures (catadioptric lenses), using holographic lenses, and/or other lens systems. When a user's eyes are located in the eye boxes, the displays (display panels) operate together to form a display for device **10** (e.g., the images provided by respective left and right optical modules may be viewed by the user's eyes in the eye boxes so that a stereoscopic image is created for the user). The left image from the left optical module fuses with the right image from a right optical module while the display is viewed by the user.

[0027] In other arrangements, device **10** may be a wrist-mounted device such as a wristwatch, a health monitoring device, a media player, a wireless key, or other electronic device and/or equipment that includes the functions of two or more of these devices or other suitable devices. The wrist-mounted device may include a housing (e.g., a housing formed from metal, ceramic, plastic, glass, sapphire or other crystalline materials, and/or other suitable materials) and a display such as a liquid crystal display, an organic light-emitting diode display, or other suitable display.

[0028] Other configurations may be used for device **10**. In general, device **10** may be any suitable wearable electronic device.

[0029] Strap **46** may have portions attached to opposing sides of device **10**. Strap **46** may be configured to wrap around a user's head, wrist, or other body part.

[0030] To allow strap **46** to stretch and fit snugly but comfortably around the user's body, strap **46** may incorporate one or more stretchable materials such as stretchable polyurethane, polyethylene terephthalate, silicone, elastomeric silicon, and/or other elastomeric materials. Due to the presence of stretchable materials in strap **46**, strap **46** may return to its original length after being stretched to fit onto the user's body. This allows a user to stretch strap **46** around the user's body. If desired, the fabric forming strap **46** may contain non-stretchable strands of material (e.g., polyester, etc.). Non-stretchable strands of material may, for example, be used to provide strap **46** with strength and/or moisture management capabilities. Arrangements in which strap **46** is formed from post-consumer recycled plastics such as post-consumer recycled polyethylene terephthalate drawn textured yarn may sometimes be described herein as an illustrative example.

[0031] A schematic diagram of an illustrative electronic device such as a head-mounted device or other wearable device is shown in FIG. **2**. Device **10** of FIG. **2** may be operated as a stand-alone device and/or the resources of device **10** may be used to communicate with external electronic equipment. As an example, communications circuitry in device **10** may be used to transmit user input information, sensor information, and/or other information to external electronic devices (e.g., wirelessly or via wired connections). Each of these external devices may include components of the type shown by device **10** of FIG. **2**.

[0032] As shown in FIG. **2**, a wearable device such as device **10** may include control circuitry **20**. Control circuitry **20** may include storage and processing circuitry for supporting the operation of device **10**. The storage and processing circuitry may include storage such as nonvolatile memory (e.g., flash memory or other electrically-programmable-read-only memory configured to form a solid state drive), volatile memory (e.g., static or dynamic random-access-memory), etc. Processing circuitry in control circuitry **20** may be used to gather input from sensors and other input devices and may be used to control output devices. The processing circuitry may be based on one or more microprocessors, microcontrollers, digital signal processors, baseband processors and other wireless communications circuits, power management units, audio chips, application specific integrated circuits, etc. During operation, control circuitry **20** may use display(s) **14** and other output devices in providing a user with visual output and other output.

[0033] To support communications between device **10** and external equipment, control circuitry **20** may communicate using communications circuitry **22**. Circuitry **22** may include antennas, radio-frequency transceiver circuitry, and other wireless communications circuitry and/or wired communications circuitry. Circuitry **22**, which may sometimes be referred to as control circuitry and/or control and communications circuitry, may support bidirectional wireless communications between device **10** and external equipment (e.g., a companion device such as a computer, cellular telephone, or other electronic device, an accessory such as a point device, computer stylus, or other input device, speakers or other output devices, etc.) over a wireless link. For example, circuitry **22** may include radio-frequency transceiver circuitry such as wireless local area network transceiver circuitry configured to support communications over a wireless local area network link, near-field communications transceiver circuitry configured to support communi-

cations over a near-field communications link, cellular telephone transceiver circuitry configured to support communications over a cellular telephone link, or transceiver circuitry configured to support communications over any other suitable wired or wireless communications link. Wireless communications may, for example, be supported over a Bluetooth® link, a WiFi® link, a wireless link operating at a frequency between 10 GHz and 400 GHz, a 60 GHz link, or other millimeter wave link, a cellular telephone link, or other wireless communications link. Device **10** may, if desired, include power circuits for transmitting and/or receiving wired and/or wireless power and may include batteries or other energy storage devices. For example, device **10** may include a coil and rectifier to receive wireless power that is provided to circuitry in device **10**.

[0034] Device **10** may include input-output devices such as devices **24**. Input-output devices **24** may be used in gathering user input, in gathering information on the environment surrounding the user, and/or in providing a user with output. Devices **24** may include one or more displays such as display(s) **14**. Display(s) **14** may include one or more display devices such as organic light-emitting diode display panels (panels with organic light-emitting diode pixels formed on polymer substrates or silicon substrates that contain pixel control circuitry), liquid crystal display panels, microelectromechanical systems displays (e.g., two-dimensional mirror arrays or scanning mirror display devices), display panels having pixel arrays formed from crystalline semiconductor light-emitting diode dies (sometimes referred to as microLEDs), and/or other display devices.

[0035] Sensors **16** in input-output devices **24** may include force sensors (e.g., strain gauges, capacitive force sensors, resistive force sensors, etc.), audio sensors such as microphones, touch and/or proximity sensors such as capacitive sensors such as a touch sensor that forms a button, trackpad, or other input device), and other sensors. If desired, sensors **16** may include optical sensors such as optical sensors that emit and detect light, ultrasonic sensors, optical touch sensors, optical proximity sensors, and/or other touch sensors and/or proximity sensors, monochromatic and color ambient light sensors, image sensors, fingerprint sensors, iris scanning sensors, retinal scanning sensors, and other biometric sensors, temperature sensors, sensors for measuring three-dimensional non-contact gestures ("air gestures"), pressure sensors, sensors for detecting position, orientation, and/or motion (e.g., accelerometers, magnetic sensors such as compass sensors, gyroscopes, and/or inertial measurement units that contain some or all of these sensors), health sensors such as blood oxygen sensors, heart rate sensors, blood flow sensors, and/or other health sensors, radio-frequency sensors, depth sensors (e.g., structured light sensors and/or depth sensors based on stereo imaging devices that capture three-dimensional images), optical sensors such as self-mixing sensors and light detection and ranging (lidar) sensors that gather time-of-flight measurements, humidity sensors, moisture sensors, gaze tracking sensors, electromyography sensors to sense muscle activation, facial sensors, and/or other sensors. In some arrangements, device **10** may use sensors **16** and/or other input-output devices to gather user input. For example, buttons may be used to gather button press input, touch sensors overlapping displays can be used for gathering user touch screen input, touch pads may be used in gathering touch input, microphones may be used for gathering audio input, accelerometers may be used in monitoring when a finger contacts an input surface and may therefore be used to gather finger press input, etc.

[0036] If desired, electronic device **10** may include additional components (see, e.g., other devices **18** in input-output devices **24**). The additional components may include haptic output devices, actuators for moving movable housing structures, audio output devices such as speakers, light-emitting diodes for status indicators, light sources such as light-emitting diodes that illuminate portions of a housing and/or display structure, other optical output devices, and/or other circuitry for gathering input and/or providing output. Device **10** may also include a battery or other energy storage device, connector ports for supporting wired communication with ancillary equipment and for receiving wired power, and other circuitry.

[0037] A knitting machine or other equipment may be used in forming strap **46**. FIG. **3** is a schematic diagram of an illustrative knitting system. As shown in FIG. **3**, strand source **66** in knitting system **64** may be used in supplying strands **68** to guide and needle structures **70**. Structures **70** may include strand guide structures (e.g., a system of movable guide bars with eyelets that guide strands **68**) 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 **64** to manipulate the positions of guide bars and needles in system **70** and thereby knit strands **68** into fabric **12**. Take down **74** (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.

[0038] A layer of illustrative knit fabric **12** is shown in FIG. **4**. A knit fabric is made up of courses **78** (e.g., rows of loops formed by strands **68**) and wales **76** (e.g., columns of loops formed by strands **68**). In a weft knit fabric of the type shown in FIG. **4** (sometimes referred to as a flat knit fabric), strands **68** form loops that extend horizontally across the fabric. An illustrative strand **68'** among strands **68** has been highlighted to show the horizontal path taken by each strand **68** in fabric **12**. In contrast, a warp knit fabric includes wales **76** formed from strands **68** that follow zig-zag paths vertically down the fabric.

[0039] The example of FIG. **4** is merely illustrative. Fabric **12** of strap **46** may include warp knit fabric, weft knit fabric, flat knit fabric, circular knit fabric, braided fabric, woven fabric, spacer fabric (e.g., inner and outer warp knit fabric layers joined by a spacer layer), and/or fabric formed using any other interlacing technique. Arrangements in which fabric **12** of strap **46** is a knit fabric are sometimes described herein as an example.

[0040] FIG. **5** is a front view of an illustrative strap formed from fabric. As shown in FIG. **5**, strap **46** may include fabric **12**. To accommodate the user's body (e.g., head, wrist, etc.), strap **46** may include different regions with different properties such as different amounts of stretch and cushioning. Some regions of strap **46** may include pockets whereas other regions of strap **46** may be free of pockets. Some regions of strap **46** may include ribs whereas other regions of strap **46** may be free of ribs. In the example of FIG. **5**, strap **46** includes one or more ribbed regions such as ribbed region **50**

and one or more smooth regions (e.g., regions without ribs) such as smooth end portions **48**. Ribbed region **50** may be formed from a ribbed fabric and may include ribs **52** (e.g., elongated strip-shaped protrusions extending parallel to the Z-axis of FIG. **5** or extending along any other suitable direction). Ribs **52** of ribbed region **50** may extend across the entirety of strap **46** except for smooth regions **48**, if desired. In other arrangements, smooth regions **48** may be omitted and ribs **52** may extend from edge-to-edge on strap **46**.

[0041] Ribbed region **50** may be used in portions of strap **46** where extra cushion is needed such as portions contacting the back of a user's head. Smooth regions **48** may be used in portions of strap **46** that connect to other support structures in device **10**. For example, smooth regions **48** may be coupled to rigid support structures near the user's ears or temples and/or may be coupled directly to main housing portion of device **10**. Ribbed region **50** and smooth regions **48** may be formed from a single piece of fabric or may be formed from multiple pieces of fabric that are attached together using stitching, adhesive, hook-and-loop fasteners, and/or any other suitable attachment structure.

[0042] Smooth regions **48** of strap **46** may be formed from knit fabric, woven fabric, and/or any other suitable type of fabric. In the example of FIG. **5**, smooth regions **48** are formed from flat knit fabric portions **56** (e.g., flat knit fabric of the type shown in FIG. **4**). Ribbed region **50** may be interposed between a first flat knit portion **56** and a second flat knit portion **56**. Flat knit portions **56** may be configured to attach to the housing of device **10**. Ribbed region **50** may extend around the back of a user's head, over the top of a user's head, around a user's wrist, etc.

[0043] Strap **46** may include one or more pockets (e.g., gaps between portions of fabric **12**). In the example of FIG. **5**, strap **46** includes pockets such as pocket **62**.

[0044] Pockets such as pocket **62** may be bounded by portions of fabric **12**. For example, dashed line **90** may indicate an inner boundary of pocket **62**, whereas the outermost perimeter **92** of strap **46** may indicate an outer boundary of pocket **62**. Along lines **90** and **92**, upper and lower portions of fabric **12** may be attached together to form walls that define pocket **62**. In the regions between lines **90** and **92**, upper and lower portions of fabric **12** may be detached from one another to form a gap or cavity.

[0045] Pocket **62** may be located in ribbed region **50**, or pocket **62** may be located in a border area of strap **46** that does not have ribs. Pocket **62** may be configured to receive a cord such as cord **80**. Cord **80** may be formed from braided strands of material, strands of material wrapped or twisted around a core, conductive strands, insulating strands, and/or other suitable materials. Cord **80** may be used to provide structure to the edges of strap **46** and/or may be used to provide adjustability to strap **46**. For example, a user may be able to adjust how tightly strap **46** fits on the user's head or wrist by adjusting cord **80** in pocket **62**. In other arrangements, cord **80** may be an electrical cable that is used to convey electrical signals.

[0046] In ribbed region **50**, fabric **12** may include an inner stretchable fabric layer such as inner fabric layer **58**. Inner fabric layer **58** may be formed from mesh fabric that allows layer **58** to stretch in directions **84**. To provide cushioning on stretchable inner layer **58**, fabric **12** may include one or more ribs such as ribs **52**. Ribs **52** may be formed on one or both sides of inner fabric layer **58**. For example, a first set of ribs **52** may be located on a first side of inner fabric layer **58**, and a second set of ribs **52** may be located on a second opposing side of inner fabric layer **58**. Ribs **52** may be formed from ottoman ribs, bengaline ribs, and/or any other suitable ribbed fabric construction. Ribs **52** may, for example, formed hollow (e.g., air-filled) protrusions on inner fabric layer **58**. In other words, air pockets may be present in ribbed region **50** between the strands **68** that form ribs **52** and the strands **68** that form inner fabric layer **58**. The presence of air inside of ribs **52** allows strap **46** to remain breathable and lightweight, while still having sufficient cushion to provide extra padding on the user's head.

[0047] If desired, fabric **12** that forms inner fabric layer **58** may have a lower gauge (e.g., a lower number of needles per inch) than fabric **12** that forms ribs **52**. For example, the gauge of inner fabric layer **58** may be equal to one-half of the gauge of the fabric that forms ribs **52**. By skipping a needle in inner fabric layer **58**, larger openings may be present in inner fabric layer **58**, thereby forming a stretchable mesh fabric layer that expands in directions **84** when device **10** is being worn and retracts back to its original position when device **10** is not being worn. Although ribs **52** have a higher gauge than inner fabric layer **58** and may therefore require more force to extend, ribs **52** may be formed on inner fabric layer **58** without increasing the required force needed to stretch strap **46** in directions **84**. In particular, ribs **52** may have sufficient height relative to inner fabric layer **58** such that ribs **52** can freely expand and retract with inner fabric layer **58**. The height of ribs **52** may be determined by the number of rows of loops that are used to form ribs **52**. Each rib **52** may be formed with a higher number of rows of loops than that used to form the portion of inner fabric layer **58** under that given rib **52**, so that ribs **52** can move with inner fabric layer **58** without actually requiring any stretching from ribs **52**.

[0048] If desired, load-modifying structures may be incorporated into ribs **52** to increase the initial force required to extend strap **46** in directions **84**, while still allowing strap **46** to remain comfortable during wear. This is described in connection with FIGS. **6-16**.

[0049] Ribs **52** may extend perpendicular to the direction of desired stretch. For example, as shown in FIG. **5**, ribs **52** extend parallel to the Z-axis, which allows ribs **52** to stretch in directions **84** (e.g., parallel to the X-axis) when strap **46** is placed on a user's head or wrist. This is merely illustrative, however. Ribs **52** may extend in any suitable direction (e.g., parallel to the X-axis, oriented at an angle between the X-axis and the Z-axis, etc.). Arrangements in which different ribs **52** follow different paths may also be used. Ribs **52** may be segmented, curved, zig-zagged, oriented in different angles, etc. Ribs **52** may all have the same size and be formed from the same materials and fabric construction, or ribs **52** may have one or more different characteristics such as different sizes, shapes, materials, fabric construction, etc.

[0050] FIGS. **6** and **7** are perspective views of ribbed region **50** of strap **46**, showing how strap **46** may be operable in an unstretched state (FIG. **6**) and a stretched state (FIG. **7**).

[0051] As shown in FIG. **6**, strap **46** may include a first set of ribs **52** on a first side **58**A of stretchable inner fabric layer **58** and a second set of ribs **52** on a second opposing side **58**B of stretchable inner fabric layer **58**. One set of ribs **52** such as ribs **52** on first side **58**A may contact the user's head or wrist when device **10** is being worn, while the other set of

ribs **52** on second side **58**B may face away from the user's head or wrist when device **10** is being worn. Ribs **52** on first side **58**A may be offset from the ribs **52** on second side **58**B, if desired.

[0052] Ribs **52** may be filled with air pockets. In particular, openings **82** may be formed in ribs **52** and may be partially or completely filled with air. Openings **82** may extend parallel to ribs **52** (e.g., perpendicular to the direction of elongation) and may be located between the fabric that forms ribs **52** and the fabric that forms inner fabric layer **58**. This allows strap **46** to remain breathable and lightweight while still providing sufficient cushion and padding on the user's head or wrist.

[0053] When forming strap **46**, strands **68** may be knitted into rows of loops such as loops **88**. Each rib **52** may be supported by a portion of inner fabric layer **58**. During knitting operations, knitting equipment **64** may knit a first set of rows of loops **88** to form a given one of ribs **52**. The number of rows of loops **88** that are used to form each rib **52** will determine the height of that rib relative to inner fabric layer **58**. After forming a first rib **52** on a first side **58**A, knitting equipment **64** may then knit rows of loops **88** to form a given portion of inner fabric layer **58** that will support the first rib **52**. Knitting equipment **64** may then knit rows of loops **88** to form a second rib **52** on second side **58**B, followed by knitting rows of loops **88** to form another portion of inner fabric layer **58** that will support the second rib **52**. This process may continue in an alternating fashion, with knitting equipment **64** knitting rows of loops **88** for a rib on one side, then knitting rows of loops **88** to form a portion of inner fabric layer **58** for supporting that rib, then knitting rows of loops **88** for a rib **52** on the other side, then knitting rows of loops **88** to form a portion of inner fabric layer **58** for supporting that rib, etc. When strap **46** is in the unstretched state of FIG. **6**, inner fabric layer **58** may not be visible between ribs **52** (or may be barely visible between ribs **52**).

[0054] Ribs **52** may have sufficient height relative to inner fabric layer **58** so that ribs **52** can accommodate stretching of inner fabric layer **58** without increasing or significantly increasing the force needed to extend inner fabric layer **58**. The height of ribs **52** relative to inner fabric layer **58** may be determined by the number of rows of loops **88** that are used to form ribs **52** and the number of rows of loops that are used to from inner fabric layer **58**. To provide ribs **52** with sufficient height relative to inner fabric layer **58**, the number of rows of loops **88** that are used to form a given rib **52** may be greater than the number of rows of loops **88** that are used to form the portion of inner fabric layer **58** that supports that given rib **52**. This allows ribs **52** to move with inner fabric layer **58** as inner fabric layer **58** is stretched in directions **84**. For example, when device **10** is not being worn and strap **46** is in the unstretched state of FIG. **6**, ribs **52** are at a maximum height of H1 relative to inner fabric layer **58** and ribbed region **50** may have a first length L1 along the X-axis. When device **10** is being worn and strap **46** is in the stretched state of FIG. **7**, ribs **52** are at a lower height H2 (e.g., a height lower than height H1 of FIG. **6**) relative to inner fabric layer **58** and ribbed region **50** may have a second length L2 along the X-axis (e.g., a length greater than length L1). Stretching strap **46** from length L1 to length L2 may also expose more of inner fabric layer **58** between ribs **52** than when strap **46** is unstretched (see exposed width X of inner fabric layer **58** between adjacent ribs **52** of FIG. **7**). In addition to accommodating stretching of inner fabric layer **58**, ribs **52** may permit bending of inner fabric layer **58**. Strap **46** may curve around the user's head, thereby bending around one or more axes that are parallel to the direction of ribs **52**. The raised height of ribs **52** relative to inner fabric layer **58** may allow ribs **52** to move with inner fabric layer **58** as it bends, rather than inhibiting bending movement.

[0055] It may be desirable to incorporate load-modifying structures into ribs **52** to modify the force-to-elongation profile of strap **46**. For example, strap **46** may include load-modifying elements such as load-modifying structures **106** in ribs **52**. Load-modifying structures **106** may serve as parallel springs that are parallel to stretchable inner fabric layer **58**. Load-modifying structures **106** may be located in some or all of ribs **52** on one or both sides of fabric layer **58**. For example, load-modifying structures **106** may be located only on side **58**A of layer **58**, may be located only on side **58**B of layer **58**, may be located on both sides **58**A and **58**B of layer **58**, may be located in every other rib **52**, every rib **52**, every 3-5 ribs **52**, only in one, two, three, or more than three ribs **52** on a given side of fabric layer **58**, and/or may be located in any other suitable pattern.

[0056] Load-modifying structures **106** may be used to increase the initial force required to stretch strap **46**, while allowing additional elongation to occur without requiring increasing force once a certain elongation percentage is reached. Load-modifying structures **106** (sometimes referred to as springs, spring members, elastic members, stiffeners, stiffening structures, etc.) may be located at a non-zero distance D from inner fabric layer **58** when strap **46** is in the unstretched state of FIG. **6**. This allows load-modifying structures **106** to only be loaded when strap **46** is stretched to a given degree. When strap **46** starts being stretched, load-modifying structures **106** may increase the initial force required to stretch strap **46**. As elongation of strap **46** increases, however, distance D between load-modifying structures **106** and inner fabric layer **58** reduces and load-modifying structures **106** approach the same plane as inner fabric layer **58**. This allows additional elongation to occur while the load remains unchanged.

[0057] Load-modifying structures **106** may be formed from a cross-stitch across opening **82** of rib **52**, a cross-stitch across the top of rib **52**, an elastomeric material that spans across opening **82** of rib **52**, that is located on top of rib **52** (e.g., a rubber cap on top of rib **52**), and/or that is otherwise integrated into rib **52**, a fabric layer (e.g., a strip of knit fabric, woven fabric, braided fabric, etc.) or other strip of material that spans across opening **82** of rib **52**, a metal or plastic rod that runs around an inside edge of rib **52**, a plasticized or fused portion of rib **52**, a coating on inner and/or outer surfaces of rib **52** (e.g., an elastic film, a layer of adhesive, and/or other stiffening layer on rib **52**), a spring that spans across opening **82** of rib **52**, a permanently or removably attached layer (e.g., a fabric layer, plastic layer, etc.) in rib **52** containing a parallel spring, and/or any other suitable load-modifying element. Load-modifying structures **106** may be permanently integrated into ribs **52** or may be removably coupled to ribs **52** to allow for a modular approach to modifying the force-to-elongation profile of strap **46**. Illustrative examples of load-modifying structures **106** are described in connection with FIGS. **9**-**15**.

[0058] FIG. **8** is a graph showing illustrative force-to-elongation profiles for fabric straps such as fabric strap **46**. Curve **104** illustrates a linear force-to-elongation profile,

which may represent the stretch behavior of a fabric strap such as fabric strap **46** that does not include load-modifying structures **106** (e.g., when load-modifying structures **46** have been removed and/or are otherwise absent from strap **46**). As illustrated by curve **104**, increasing elongation of strap **46** results in increasing force in the absence of load-modifying structures **106**. In contrast, curve **102** illustrates a stepwise force-to-elongation profile, which may represent the stretch behavior of a fabric strap such as fabric strap **46** that includes load-modifying structures **106**. As illustrated by curve **102**, an initial force F1 is applied during the initial stretching of strap **46**, as load is applied to load-modifying structures **106**. As strap **46** is stretched further, however, the distance D between load-modifying structures **106** and inner fabric layer **58** approaches zero, thereby allowing additional elongation to occur while force F1 remains unchanged. This may result in strap **46** being able to stretch to longer lengths (e.g., to accommodate larger heads and/or larger wrists) while strap **46** remains comfortable during wear.

[0059] FIG. **9** is a side view of a portion of strap **46** illustrating how a given rib may include multiple load-modifying structures located at different distances from the main inner fabric layer **58**. As shown in FIG. **9**, rib **52** may include multiple load-modifying structures **106** such as first and second parallel spring members **110**. Each spring member **110** may span across opening **82** of rib **52** and may have a first end coupled to a first sidewall **52**P of rib **52** and a second opposing end coupled to a second opposing sidewall **52**P of rib **52**. Spring members **110** may be located at different heights relative to inner fabric layer **58**. A first spring member **110** may be located at distance D1 relative to inner fabric layer **58**, while a second spring member **110** may be located at distance D2 relative to inner fabric layer **58** (e.g., a distance greater than distance D1). Both spring members **110** may increase the initial load required to stretch strap **46**, but the required load may flatten out (as illustrated by curve **102** of FIG. **8**) as the distance between spring members **110** and inner fabric layer **58** approaches zero when strap **46** is stretched in directions **84**.

[0060] Spring members **110** may be formed from a cross-stitch across opening **82** of rib **52**, an elastomeric material that spans across opening **82** of rib **52**, a fabric layer (e.g., a strip of knit fabric, woven fabric, braided fabric, etc.) or other strip of material that spans across opening **82** of rib **52**, a spring that spans across opening **82** of rib **52**, a permanently or removably attached layer (e.g., a fabric layer, plastic layer, etc.) spanning across opening **82** of rib **52** and containing a spring, and/or any other suitable load-modifying element. Spring members **110** may be permanently or removably attached to sidewalls **52**P of rib **52**.

[0061] The example of FIG. **9** in which load-modifying structures **106** include first and second spring members **110** is merely illustrative. If desired, fewer than two or more than two (e.g., three, four, five, etc.) spring members may span across opening **82** in rib **52**. Spring members **110** may have the same construction and/or may be formed from the same material, or spring members **110** may have different construction and/or may be formed from different materials. Spring members **110** may be formed in ribs **52** on one or both of sides **58**A and **58**B of inner fabric layer **58**, as shown in FIGS. **6** and **7**.

[0062] FIGS. **10-15** show illustrative examples of load-modifying structures **106** that may be incorporated into or otherwise coupled to ribs **52** on one or both sides of inner fabric layer **58**.

[0063] In the example of FIG. **10**, load-modifying structures **106** include material **112** integrated into the upper portions of ribs **52**. In some arrangements, material **112** may be a portion of fabric **12** that forms an upper portion of ribs **52**. Material **112** may be formed from the same material as the rest of ribs **52** or may be formed from a different material. For example, material **112** may be formed from fused strands of material, a plasticized portion of ribs **52** (e.g., material **112** may include heat-treated plastic), may be formed from elastomeric material (e.g., rubber), metal, adhesive, epoxy, film, and/or any other suitable material that increases the bending stiffness of the upper portion of rib **52** and/or at least a portion of sidewalls **52**P of ribs **52**. Material **112** may be a portion of rib **52** or may be a material that is attached to, coated onto, or otherwise located an outer surface of rib **52**. Material **112** may span across some or all of width W of strap **46**.

[0064] In the example of FIG. **11**, load-modifying structures **106** include material **114** that fills some or all of opening **82** in ribs **52**. Material **114** may be formed from metal, plastic, elastomer (e.g., rubber), fabric (e.g., fused fabric, multiple layers of fabric, spacer fabric, braided fabric, knit fabric, woven fabric, etc.), metal rods, plastic rods, adhesive, epoxy, and/or other suitable structures and/or materials. Material **114** may be directly attached to rib **52** or may be coupled to rib **52** via one or more attachment structures or materials such as a layer of adhesive. Material **114** may be permanently or removably attached to rib **52**. In the example of FIG. **11**, material **114** only partially fills openings **82** in ribs **52**, thereby allowing air to flow between material **114** and inner fabric layer **58** (e.g., so that inner fabric layer **58** remains breathable). Material **114** may span across some or all of width W of strap **46**.

[0065] In the example of FIG. **12**, load-modifying structures **106** include stitching **116**. Stitching **116** may be formed from one or more strands of material (e.g., a monofilament thread, a multifilament yarn, a cord, a braided strand, a twisted strand, a strip of fabric, etc.) that spans across opening **82** in ribs **52**. If desired, stitching **116** may span back and forth between sidewalls **52**P of ribs **52** along some or all of width W of strap **46**, as shown in the example of FIG. **12**. In other arrangements, stitching **116** may include separate, parallel strand segments that span across opening **82** at different locations along width W of strap **46**.

[0066] In the example of FIG. **13**, load-modifying structures **106** include strips of material **118** that span across respective openings **82** in ribs **52**. Material **118** may be a layer of fabric (e.g., knit fabric, woven fabric, braided fabric, spacer fabric, fused fabric, etc.), a layer of elastic material (e.g., rubber or other elastomer), a layer of metal, a layer of plastic, and/or a layer of any other suitable material. Strip **118** may include a first side coupled to first sidewall **52**P of rib **52** and a second opposing side coupled to second opposing sidewall **52**P of rib **52**. If desired, strip **118** may span across the entire width W of strap **46**, as shown in the example of FIG. **13**. In other arrangements, strip **118** may only span across a portion of width W and/or may include multiple parallel strip segments that span across opening **82** at different locations along width W of strap **46**. Strips **118** may be permanently or removably attached to ribs **52**.

[0067] In the example of FIG. **14**, load-modifying structures **106** include springs **120** that span across respective openings **82** in ribs **52**. Each spring **120** may have a first end coupled to first sidewall **52**P of rib **52** and a second opposing end coupled to second opposing sidewall **52**P of rib **52**. There may be one, two, three, four, eight, more than eight, or less than eight springs **120** located at different positions along width W of strap **46**. Springs **120** may be permanently or removably attached to ribs **52**.

[0068] In the example of FIG. **15**, load-modifying structures **106** include material **124** that forms part of and/or is located on an upper portion of rib **52** and material **126** that spans across opening **82** of rib **52**. In some arrangements, material **124** may be a portion of fabric **12** that forms an upper portion of ribs **52**. Material **124** may be formed from the same material as the rest of ribs **52** or may be formed from a different material. For example, material **124** may be formed from fused strands of material, a plasticized portion of ribs **52** (e.g., material **124** may include heat-treated plastic), may be formed from elastomeric material (e.g., rubber), metal, adhesive, epoxy, film, and/or any other suitable material that increases the bending stiffness of the upper portion of rib **52** and/or at least a portion of sidewalls **52**P of ribs **52**. Material **124** may be a portion of rib **52** or may be a material that is attached to, coated onto, or otherwise located on an outer or inner surface of rib **52**. Material **124** may span across some or all of width W of strap **46**.

[0069] Material **126** may span across opening **82** of rib **52** and may have a first side coupled to first sidewall **52**P of rib **52** and a second opposing side coupled to second opposing sidewall **52**P of rib **52**. Material **126** may be formed from a cross-stitch across opening **82** of rib **52**, an elastomeric material that spans across opening **82** of rib **52**, a fabric layer (e.g., a strip of knit fabric, woven fabric, braided fabric, etc.) or other strip of material that spans across opening **82** of rib **52**, a spring that spans across opening **82** of rib **52**, a permanently or removably attached layer (e.g., a fabric layer, plastic layer, etc.) spanning across opening **82** of rib **52** and containing a spring, and/or any other suitable load-modifying element. Material **126** may be permanently or removably attached to sidewalls **52**P of rib **52**.

[0070] If desired, two or more layers of material **126** may be located at different heights relative to inner fabric layer **58**. For example, a first layer of material **126** may be located at a first distance relative to inner fabric layer **58**, while a second layer of material **126** may be located at a second distance D2 relative to inner fabric layer **58** (e.g., as in the example of FIG. **9**).

[0071] In the example of FIG. **16**, strap **46** includes an elastic layer such as stretchable layer **130** (e.g., a mesh layer which may form inner fabric layer **58** of FIGS. **6**, **7**, and **9-15**), a compressible layer **132** (e.g., a layer of foam, spacer fabric, and/or other compressible material), and outer stiffening layer **134**. Layers **134**, **132**, and **130** may be attached using attachment structures **136** at the edges of strap **46**. Attachment structures **136** may include stitching, adhesive, welding, clasps, clips, and/or any other suitable attachment structures.

[0072] Stiffening layer **134** may be a layer of fabric, metal, plastic, or other suitable material having less elasticity than inner fabric layer **130**. As fabric strap **46** is stretched in directions **84**, compressible layer **132** may compress and the distance between outer stiffening layer **134** and inner stretchable layer **130** may decrease. Similar to load-modifying structures **106**, stiffening layer **134** may increase the initial force required to stretch strap **46**, but the required force to elongate further may flatten out past a given elongation percentage as stiffening layer **134** approaches the same plane as stretchable inner fabric layer **130**.

[0073] As described above, one aspect of the present technology is the gathering and use of information such as information from input-output devices. The present disclosure contemplates that in some instances, data may be gathered that includes personal information data that uniquely identifies or can be used to contact or locate a specific person. Such personal information data can include demographic data, location-based data, telephone numbers, email addresses, twitter ID's, home addresses, data or records relating to a user's health or level of fitness (e.g., vital signs measurements, medication information, exercise information), date of birth, username, password, biometric information, or any other identifying or personal information.

[0074] The present disclosure recognizes that the use of such personal information, in the present technology, can be used to the benefit of users. For example, the personal information data can be used to deliver targeted content that is of greater interest to the user. Accordingly, use of such personal information data enables users to calculated control of the delivered content. Further, other uses for personal information data that benefit the user are also contemplated by the present disclosure. For instance, health and fitness data may be used to provide insights into a user's general wellness, or may be used as positive feedback to individuals using technology to pursue wellness goals.

[0075] The present disclosure contemplates that the entities responsible for the collection, analysis, disclosure, transfer, storage, or other use of such personal information data will comply with well-established privacy policies and/or privacy practices. In particular, such entities should implement and consistently use privacy policies and practices that are generally recognized as meeting or exceeding industry or governmental requirements for maintaining personal information data private and secure. Such policies should be easily accessible by users, and should be updated as the collection and/or use of data changes. Personal information from users should be collected for legitimate and reasonable uses of the entity and not shared or sold outside of those legitimate uses. Further, such collection/sharing should occur after receiving the informed consent of the users. Additionally, such entities should consider taking any needed steps for safeguarding and securing access to such personal information data and ensuring that others with access to the personal information data adhere to their privacy policies and procedures. Further, such entities can subject themselves to evaluation by third parties to certify their adherence to widely accepted privacy policies and practices. In addition, policies and practices should be adapted for the particular types of personal information data being collected and/or accessed and adapted to applicable laws and standards, including jurisdiction-specific considerations. For instance, in the United States, collection of or access to certain health data may be governed by federal and/or state laws, such as the Health Insurance Portability and Accountability Act (HIPAA), whereas health data in other countries may be subject to other regulations and

policies and should be handled accordingly. Hence different privacy practices should be maintained for different personal data types in each country.

[0076] Despite the foregoing, the present disclosure also contemplates embodiments in which users selectively block the use of, or access to, personal information data. That is, the present disclosure contemplates that hardware and/or software elements can be provided to prevent or block access to such personal information data. For example, the present technology can be configured to allow users to select to "opt in" or "opt out" of participation in the collection of personal information data during registration for services or anytime thereafter. In another example, users can select not to provide certain types of user data. In yet another example, users can select to limit the length of time user-specific data is maintained. In addition to providing "opt in" and "opt out" options, the present disclosure contemplates providing notifications relating to the access or use of personal information. For instance, a user may be notified upon downloading an application ("app") that their personal information data will be accessed and then reminded again just before personal information data is accessed by the app.

[0077] Moreover, it is the intent of the present disclosure that personal information data should be managed and handled in a way to minimize risks of unintentional or unauthorized access or use. Risk can be minimized by limiting the collection of data and deleting data once it is no longer needed. In addition, and when applicable, including in certain health related applications, data de-identification can be used to protect a user's privacy. De-identification may be facilitated, when appropriate, by removing specific identifiers (e.g., date of birth, etc.), controlling the amount or specificity of data stored (e.g., collecting location data at a city level rather than at an address level), controlling how data is stored (e.g., aggregating data across users), and/or other methods.

[0078] Therefore, although the present disclosure broadly covers use of information that may include personal information data to implement one or more various disclosed embodiments, the present disclosure also contemplates that the various embodiments can also be implemented without the need for accessing personal information data. That is, the various embodiments of the present technology are not rendered inoperable due to the lack of all or a portion of such personal information data.

[0079] The foregoing is merely illustrative and various modifications can be made to the described embodiments. The foregoing embodiments may be implemented individually or in any combination.

What is claimed is:

1. A fabric strap for a wearable electronic device, the fabric strap comprising:

an inner fabric layer having first and second opposing surfaces, wherein the inner fabric layer is configured to elongate along a first direction;

ribs on the first and second opposing surfaces of the inner fabric layer, wherein the ribs have respective openings that each extend along a second direction perpendicular to the first direction; and

load-modifying structures in the ribs that each span across a respective one of the openings.

2. The fabric strap defined in claim **1** wherein the load-modifying structures are each separated from the inner fabric layer by a distance when the inner fabric layer is in an unstretched state.

3. The fabric strap defined in claim **2** wherein the distance decreases as the inner fabric layer elongates.

4. The fabric strap defined in claim **1** wherein the load-modifying structures comprise springs that are parallel to the inner fabric layer.

5. The fabric strap defined in claim **4** wherein the springs include multiple springs located at different positions along a respective one of the openings.

6. The fabric strap defined in claim **1** wherein the load-modifying structures comprise stitching that spans between first and second opposing sidewalls of a respective one of the ribs.

7. The fabric strap defined in claim **1** wherein the load-modifying structures comprise a layer of fabric that spans between first and second opposing sidewalls of a respective one of the ribs.

8. The fabric strap defined in claim **1** wherein the load-modifying structures comprise a layer of elastomer that spans between first and second opposing sidewalls of a respective one of the ribs.

9. The fabric strap defined in claim **1** wherein the load-modifying structures are removably attached to the ribs.

10. The fabric strap defined in claim **1** further comprising stiffening structures located in respective upper portions of the ribs and separated from the inner fabric layer by a gap.

11. A stretchable fabric strap configured to attach a wearable electronic device to a user, the stretchable fabric strap comprising:

ribbed fabric having a mesh inner layer that stretches along a first direction and having ribs that protrude from the mesh inner layer along a second direction perpendicular to the first direction; and

stiffening structures located in respective upper portions of the ribs and separated from the mesh inner layer by a gap.

12. The stretchable fabric strap defined in claim **11** wherein the stiffening structures comprise coatings located on the respective upper portions of the ribs and wherein the coatings comprise at least one of an elastic film and an adhesive layer.

13. The stretchable fabric strap defined in claim **11** wherein the stiffening structures comprise at least one of a metal layer and a plastic layer.

14. The stretchable fabric strap defined in claim **11** wherein the stiffening structures are removably attached to the ribs.

15. The stretchable fabric strap defined in claim **11** further comprising load-modifying structures that each span across a respective opening in the ribs.

16. A fabric strap for a wearable electronic device, the fabric strap comprising:

a stretchable inner fabric layer configured to elongate in a first direction;

a stiffening outer layer; and

a compressible layer interposed between the stretchable inner fabric layer and the stiffening outer layer, wherein the compressible layer is configured to compress as the stretchable inner fabric layer elongates to reduce a distance between the stretchable inner fabric layer and the stiffening outer layer.

17. The fabric strap defined in claim **16** wherein the stretchable inner fabric layer comprises a mesh fabric.

18. The fabric strap defined in claim **16** wherein the compressible layer comprises foam.

19. The fabric strap defined in claim **16** wherein the compressible layer comprises spacer fabric.

20. The fabric strap defined in claim **16** wherein the stiffening layer is less elastic than the stretchable inner fabric layer.

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